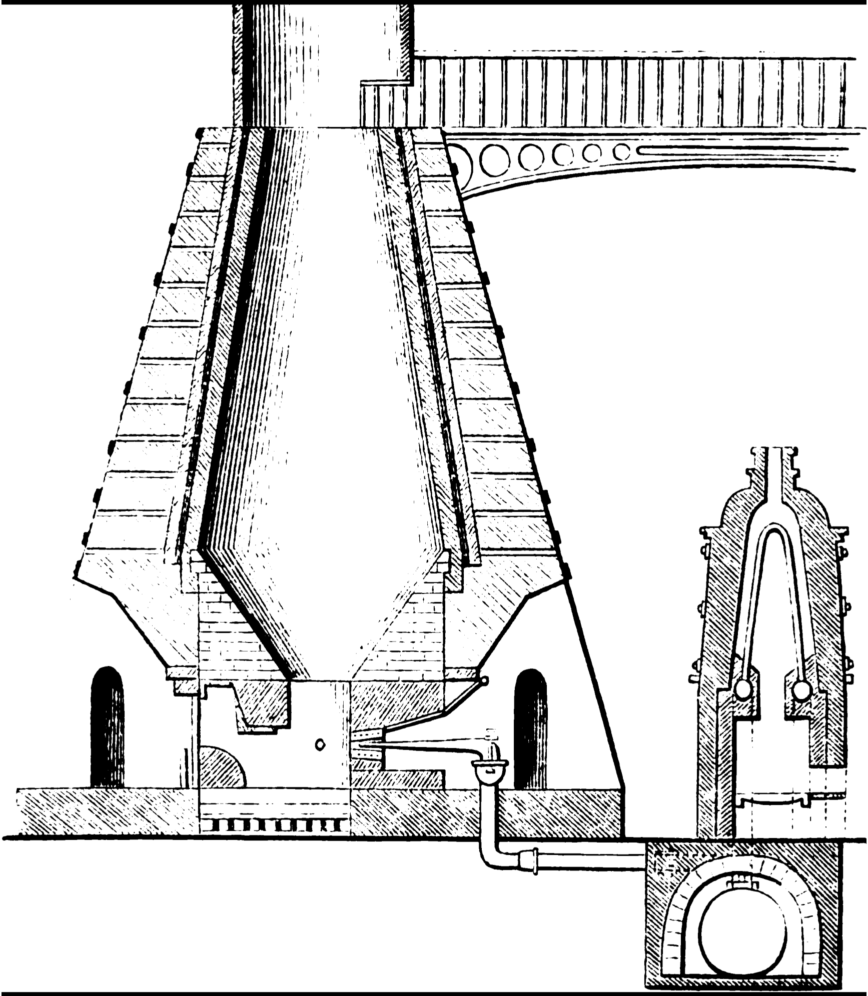

The industry of nations

Industry

THE

INDUSTRY OF NATIONS,

PART II.

A SURVEY OF THE EXISTING STATE

OF

ARTS, MACHINES, AND MANUFACTURES.

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A Survey of the Existing State

OF

ARTS, MACHINES, AND MANUFACTURES.

CHAPTER I.

MINES AND THEIR PRODUCTS.

At the earliest period one of the greatest wants of the human family must have been that of a suitable material for the implements and instruments of daily use. Certain general features in the properties of bodies, such as their tenacity, hardness, flexibility, and combustibility, would be quickly recognised; and one of the earliest attempts in reducing these bodies to the use of man would be to adapt them to those purposes for which their physical characters appeared best to fit them. Thus a hard wood would be selected for digging, and a softer and lighter kind for construction or for floating on the water. An elastic rod would be selected for a bow, a firm, resisting kind for the arrow, and a sharpened stone for its wounding point. The material would be selected with reference to the end desired to be effected by its means, and, after a little experience, the best material at hand for the particular purpose in view would be chosen. Thus corn would be ground between stones of a rough and dense texture, while lighter stones and earth would serve for the erection of the walls of the early habitations of our race. For all the implements used in the cultivation of

the earth, or as instruments of force for mechanical purposes, there was but one choice of material, and that was wood. According to their physical properties various kinds would be selected and applied by man to his wants and uses; but a little experience would soon convince him, that the use of even the most suitable kinds of wood which could be selected was attended with much inconvenience, in consequence of the impossibility of preserving its form and fitness for use in actual service. Thus, for example, a wooden spade, although very useful and of good construction in its form, would soon become valueless for practical purposes, in consequence of the destruction of its edge, and the rending of its fibres by the force employed in thrusting it into the earth. And numerous other instances might be adduced, which would tend to show that the want of a hard, flexible, elastic, tenacious, and enduring material would be constantly felt by those whose choice was limited to that supplied by the woods and forests.

If a doubt were felt as to the real existence of such a want, it may be resolved by the well-known facts of our modern intercourse with those who are still ignorant of metallurgic processes and products. The objects most earnestly sought after by untutored savages are small portions of the commoner metals, iron nails, pieces of copper and brass. This is an obvious indication that one of the very earliest requirements of man even in a savage state is the possession of suitable metals for his implements and instruments.

But metals, unlike the woods, do not exist in nature in a condition in which they can become of direct use to man. Iron, lead and copper cannot be dug out of the ground in sheets, rods, and bars. Neither, indeed, could the properties of these metals be readily discovered from such of their ores as might present themselves to view. of a block of iron ore were found by a savage he might

be surprised at its colour and density, but he could not form the remotest conception of its properties. He could not form the idea of its becoming elastic as a green bough, in the form of steel, or tenacious as a cord in that of wire, much less would he deem it capable of being spread out into a sheet like canvas, or being fused and moulded into any desired form. All the idea he could form of it would be that of a heavy, hard, compact mass, differing but little from a block of stone, and in his view as little suited to his wants and purposes. With what surprise would he learn from one to whom the reduction of this obdurate ore to a metallic state was a familiar process, that all these properties really existed in it although at present in a latent state; and that the heavy mass at his feet could be spun into thread, wrought into beautiful forms, endowed with the extraordinary properties of intense hardness, and fragility, or extreme malleability and tenacity, and with the still more wonderful power of attraction at the will of the operator! It might seem a mere fable to him; nor is it, in fact, less marvellous than many creations of fiction.

Since all the valuable properties of the common metals are in this latent condition in their native state, it may be readily supposed that their discovery was not immediate and obvious. It was possibly the result of an accident. The effect of intense heat on some masses of ore might have been noticed, and immediately upon such an observation a new field of operations was commenced. Be this as it may, it is still as ever true, that the most valued properties of the metals are not recognisable in their state as found in the earth. There lies the mass of ore, uninviting in its appearance in many cases, though in others glittering and beautiful,—yet in its state as an ore useless and valueless. Its wonderful and serviceable properties lie entirely dormant, awaiting the

call of the instructed man to assume an active condition. The sight of such a mass placed by the side of its manufactured products affords much subject for thought, and however commonplace such a spectacle may be, it can never lose the intrinsic interest it possesses for the reflective mind. In every conceivable direction, and by every possible variety of illustration, the Great Exhibition of 1851 presented such subjects for the contemplation and information of all those who were prepared or disposed to regard them with the attention they deserved. There was the crude mass, hard, dull-looking, and stone-like, and by its side was the finished product, the delicate and thread-like watch-spring, the sharp and brilliant blade, the powerful hammer, and the toiling steam-engine. It was a good and instructive lesson of the power of man over the elements with which he is placed in contact.

That this character of metallic substances in their natural state fulfils a wise end no one can doubt. Were it possible for man to obtain these most important elements in a state exactly fitted for his use, and to dig them as such out of the earth, the great incentive to thought, experiment, and enterprise would be lost. It has consequently pleased the Creator to place these substances within our reach if we will exert the mental and physical powers with which He has endowed us, upon their reduction and preparation to our use. Iron, lead, and copper cannot be cut out of the forest, but they are nevertheless obtainable if we will take pains to get them, if we will learn their properties and combinations, and diligently set ourselves to the task. If in their physical properties they surpass wood and stubble, then surely it is worth while putting ourselves to conquer some difficulties in order to obtain them. And this act is industry; its rewards are rich and abundant.

Such are the few thoughts we would lay before the

reader in commencing our present subject, under the conviction that they contain the elements of great and important truths. The whole creation of God is a scene of industry. No creature and no thing is idle. The air, the sea, the trees, the living occupants of the globe —all are busy, and man must not be idle. If he would have comforts, advantages, pleasures, and blessings, he must toil for them, and his toil will meet with its reward. If he would subdue nature to himself, and to his conveniences and uses, he must put forth his best mental and physical powers, and his success is certain. Industrial labour is in itself and in its results equally a blessing.

The contemplation of mineral substances in their natural state suggests many other directions of thought and inquiry, into which it is not expedient for us at present to enter. A few remarks, however, made by Sir Henry de la Beche appear to us to deserve our attention in commencing our present chapter on mining and metallurgical industries:—

"Mineral matter," he observes, "unlike animal and vegetable substances, cannot, in its original or natural state, be modified by man for his use. While he can obtain important varieties of animal substances, by treatment of the animals themselves, or by perpetuating certain varieties of them, and can, by culture, produce valuable modifications in plants, or their parts, no skill of his can alter the natural condition of an ore in the mine. His power commences with that of discovering the mineral matter required by him. Mineral substances have thus to be regarded, industrially, as essentially connected with the means of extraction and the after processes by which they are rendered available for use. While plants and animals differ in various regions of the earth, and the traffic connected with the raw materials they afford is adjusted to this difference,

mineral matter of the same character may be discovered in any part of the world, at the Equator or towards the Poles; at the summit of the loftiest mountains, and in works far beneath the level of the sea. The granite of Australia does not necessarily differ from that of the British Islands; and ores of the metals may (the proper geological conditions prevailing) be found of the same general character in all regions. Climate and geographical position have no influence on the composition of mineral substances.

"Though geographical position has no influence on natural mineral substances, except so far as modifications may be produced by the action of the atmosphere, it may, nevertheless, constitute a most important element among those on which depend the actual uses of those substances. All other conditions being equal, it may decide their extraction or non-extraction. Even important minerals may be so situated as to be unproductive of advantage to those endeavouring to obtain them for use. No doubt, geographical position may be modified by the labour of man, and so that the mineral matter in the same locality, which could not be profitably raised at one time, may be most advantageously worked at another. The condition of man, therefore, occupying different areas on the earth's surface as nations, becomes an element of the utmost importance as regards the useful extraction of mineral substances. The conditions under which such divisions of mankind may exist, their laws and customs, are important to the development of any mineral wealth, as it were latent in the areas occupied by them. These may either tend to impede or promote that development; and the different divisions of men may, by their regulations, act most variably on each other, and, instead of advancing their common good, introduce systems of mutual checks, to the disadvantage of all.

"The more advanced a nation, the greater, under equal general conditions, is its power over the disadvantages which may happen to be presented by geographical position, thus producing facilities for the development of its mineral wealth. The cost of transport — that frequent impediment to the profitable working of mineral substances—may become so lessened by addition to easy communications of various kinds, that finally the working of mineral substances can be changed from unprofitable to profitable. In the cases of many ores, these and the fuel needed for smelting them may be brought together by facility and cheapness of conveyance, so that industries new to a land may spring up."

Although man, by his general advance, may thus accomplish much for the development of mineral wealth, there are natural limits to his progress which cannot be overcome. Although he may effect the easy transport of mineral matter over rivers and valleys, and even through portions of the earth itself, either by his canals or his roads, and thus, as regards such transport, change the face of a country from one of difficulty to one of facility, the greater geographical arrangements remain unaltered. He cannot change an inland country, in the central position of a continent, to a maritime state, though he can materially modify its position as to the ready means of transport to the coast. An inland locality may pour in its mineral products, by means of increased facilities of transport, upon a seaport, so that not only may they replace similar substances produced at greater cost near such a port, but, by means of the sea, be transported even far to other lands, competing in their markets, should the regulations of the nations holding them permit, with those which had hitherto satisfied them.

The profitable development of mineral wealth will

therefore depend upon the natural occurrence of mineral substances, due to geological causes—upon the geographical position of the localities where the useful mineral substances are present,—and upon the condition of man in a given area. The first condition is unalterable by man, the remaining two may be most materially modified by him.

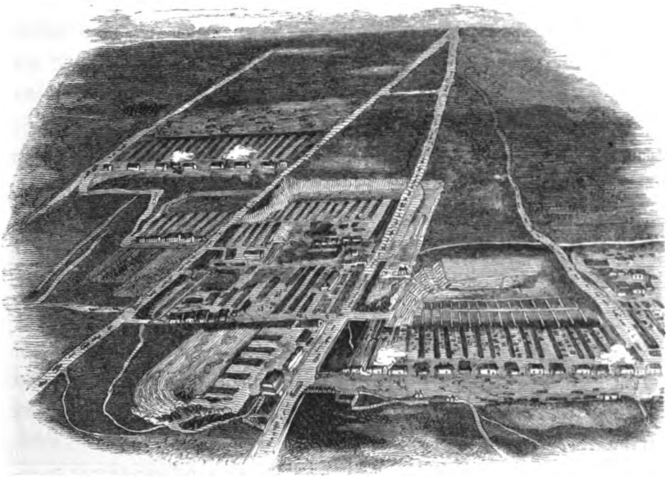
Since the subject of fuel of every kind was discussed in a volume preceding this work, it is unnecessary for us again to enter upon its elucidation. As the great element in all manufacturing processes, and the source both of power and heat, too much importance could not be given in an industrial point of view to the vast stores of fossil fuel with which the great Creator has abundantly supplied this and other countries. Separated from this all our wealthiest mineral treasures would have been of comparatively little value, and progress in the arts and sciences would have been slow and feeble. Of little use would it have been to us to have had heaps of the richest iron or copper ore on the very surface of the soil, without the fuel requisite to smelt them, and reduce them. And we shall again have occasion to notice, that by a beautiful and wonderful arrangement, the stores of fuel and of ore have in many instances been laid up in close proximity to each other, thus presenting the greatest possible advantage to the manufacturer and worker in metals.

An interesting illustration of these remarks exists in the localisation and development of the mineral manufactures of M. Miesbach, near Vienna. A bird's-eye view of his extraordinary works, and of the roads leading to Vienna, was shown at the Great Exhibition, and has been here reproduced.

The origin of these works is entirely due to the existence of excellent material for the required purpose within an easy distance of a great centre of demand;

and their extent may be estimated from the following statement.

The works produce tiles, hollow bricks, slates, &c. of all kinds, and of excellent quality. They cover 265 English acres, the drying-sheds are 24,930 feet in total



length, the moulding sheds, 8,304 feet. There are 446 moulding benches, 43 kilns capable of burning three-and-a-half million of bricks at once, fine artesian wells, stabling for 300 horses, an infant school for 120 children, a hospital with 52 beds, and 2,890 persons are employed. Sixty-five millions and-a-half of bricks and tiles are turned out every year.

Let us now advert to one of the most important of all the ores, the value of which ranks next to that of the fuel necessary to its preparation for the use of man. To her vast stores of Iron ore this country owes much of its manufacturing importance and industrial position, since the provision of a cheap and abundant source of

this metal constitutes one of the most important elements of the wealth of a nation,—far more so than of mines of the more precious metals of gold and silver. The immense iron-making resources of the United Kingdom were excellently illustrated at the Great Exhibition, and a series of specimens and models were exhibited which has never before nor since been equalled. The collection by Mr. S. Blackwell, in particular, was most extensive and judiciously arranged, and furnished to all who were interested in this department of national industry an impressive picture of the variety and extent of our mineral wealth. Some of the facts stated by Mr. Blackwell in his catalogue of ores deserve notice, since they are the result of the most recent and careful investigation and analysis:—From these we learn that the gross annual production of iron in Great Britain is now upwards of 2,250,000 tons. Of this quantity South Wales furnishes 700,000 tons; South Staffordshire (including Worcestershire) 600,000 tons; and Scotland 600,000 tons. The remainder is divided amongst the various smaller districts.

One of the principal causes of the advantages possessed by Great Britain in the manufacture of iron, arises from the number and variety of the measures of argillaceous and black-band ironstones which alternate with the beds of coal in almost all its coal-fields; and in consequence of which, the same localities, and, in many instances, the same mineral workings, frequently furnish both the ore and the fuel required to smelt it.

So extensive are the ironstone beds of the coal measures, that they furnish in themselves the greater part of the iron produced in Great Britain; but the iron-making resources of the kingdom are by no means confined to them. The carboniferous, or mountain limestones of Lancashire, Cumberland, Durham, the Forest

of Dean, Derbyshire, Somersetshire, and South Wales, all furnish important beds and veins of hæmatite; those of Ulverston, Whitehaven, and the Forest of Dean are the most extensively worked, and seem to be almost exhaustless. The brown hæmatites and white carbonates of Alston Moor and Weardale also exist in such large masses that they must ultimately become of great importance. In the older rocks of Devon and Cornwall are found many important veins of black hæmatite, and in the granite of Dartmoor numerous veins of magnetic oxide and specular iron ore. The new red sandstone furnishes in its lowest measures beds of hæmatitic conglomerate. In the lias and oolites are important beds of argillaceous ironstones, now becoming extensively worked; and the iron ores of the greensand of Sussex, once the seat of a considerable manufacture of iron, will, in all probability, again soon become available, by means of the facilities of railway communication.

The produce of the manufacture of iron in Great Britain in 1750 was only about 30,000 tons; in 1800, it had increased to 180,000 tons; in 1825, to 600,000 tons; in the following year the duties upon the introduction of foreign iron were either removed or rendered nominal, since which the production of iron has nearly quadrupled itself, being now about 2,250,000 tons.

This enormous development of the iron trade has been occasioned by the steam engine, the manufacturing machine, the iron ship and the railroad. In all other directions, in the domestic arts, and even in the arts of construction, the demand for iron has not increased in the same ratio as it has done in the directions indicated. What thousands of tons of iron have been stretched in a tangled network over the face of this country, in the form of railways; and how vast the weight of those iron machines, wheels, and carriages which are borne across

these metal ways! Again, what immense quantities of iron are annually consumed in our great manufacturing towns for machinery and hardware, in Manchester and Birmingham! For these and for various other purposes does this vast iron production of two and a quarter million tons annually form the supply.

The ores which constitute the principal sources of metallic iron in this country, are its oxides and carbonates. These are, however, seldom found without much admixture of foreign matters, and requiring, consequently, a series of processes, by which these shall be discharged, and the pure metal left. The peroxide of iron, called red hæmatite, which is one of the most valued of the ores of this metal, consists of about seventy parts of iron and thirty parts of oxygen. The other kinds of hæmatite ore, black and brown, contain, in addition to the oxygen, a variable proportion of water and of earthy constituents.

Red hæmatite exists in many parts of this and of other countries. It is often known by the term specular iron ore, and presents frequently a most brilliant appearance, forming beautiful crystals, especially in volcanic districts. It is a very rich ore, but has the disadvantage of being difficult to smelt when employed by itself. It is on this account largely used for the purpose of mixing with other ores more easily ground, but containing a smaller percentage of iron. By this means a very superior kind of iron may be obtained. Brown hæmatite is often mixed with earthy matter, and is not so valuable an iron for the purposes of the metallurgist as the former kind.

Carbonate of iron, often called spathose iron, constitutes one of the most abundant and valuable ores of this metal, and is often associated with ores of other metals, as lead and copper. It exists in this country chiefly in deposits alternating with beds of coal, and is conse-

quently so situated as to be readily and economically worked. It is often in fact extracted from the same pits by which the coals are raised to the surface. The principal deposits of carbonate of iron in the United Kingdom are those of Dudley—the products of which are chiefly sent to Liverpool, those of Glasgow and those of Wales.

Another ore much used as a source of excellent iron is the magnetic iron ore. It has certain peculiarities which have received attention. It is very dense, is strongly attracted by the magnet, and possesses occasionally magnetic properties of its own. It appears to consist of a protoxide and a peroxide of the metal. It is largely used in Sweden for the manufacture of the valuable iron obtained from that country.

These and other iron ores are, as we have said, seldom found in a pure state, and often contain admixtures of foreign substances which greatly diminish their value, while occasionally they are united with such as enhance their utility to man. Among the former, minute portions of phosphorus must be particularly noticed. It is found that this elementary substance possesses the singular property, even in very small proportions, of rendering the metal produced from ores which contain it extremely brittle, and often to such an extent as to be absolutely valueless. Small quantities of manganese, of magnesia and of lime, which assist in liquefying the clay, are on the contrary valuable additions, and produce excellent iron.

The iron ores of other countries resemble those of our own in their essential composition, but at the same time often exhibit local peculiarities, rendering them either more or less adapted to the purposes of metallurgy. A brief sketch of these, as they were represented at the Great Exhibition, we shall now proceed to give. Our colonies and dependencies possess vast stores of this

valuable metal in the form of excellent ores, and many of these are situated in the most advantageous positions for its extraction and manufacture. In Canada especially beds of iron ore are found in the greatest abundance and often of the purest kind. The beds they form range from four and six feet to two hundred feet in thickness. Much magnetic iron ore and specular iron is found in this colony. The ores obtained near Crow Lake and smelted at the Marmora iron works are so rich that they are said to yield from 60 to 70 per cent. of pure metal, our own ores not averaging more than about half this proportion. In addition to these, excellent iron is obtained from another species of iron ore, very abundant in the province, — the hydrated peroxide or bog ore. From an extensive deposit of this ore the St. Maurice forges, near Three Rivers, on the t. Lawrence, have been supplied for half a century. Specimens of it, with the wrought-iron there manufactured from it, were exhibited in the form of ploughshare and axe iron, as well as cold-folded and cold-twisted bars, showing its excellent quality. Large blocks were shown also from workable sources at Vaudreuil, on the Ottawa; at Rivière du Chêne, Pontneuf, Rivière du Sud, below Quebec, and many other places, the yield of all of which is on an average between 40 and 50 per cent. of pure iron. The forests of the country are capable of furnishing an unbounded supply of wood for fuel near the different localities of all these species of iron ore, affording an opportunity for manufacture equal to that possessed by Sweden, with whose produce the iron made in the colony at present competes. Most of the districts mentioned have the advantage of great water power for driving machinery, and many of them are near navigable rivers.

From the East Indies also specimens of good ores were sent, and among them those from which the cele-

brated Wootz steel is obtained. Very superior ores exist also in New Brunswick and Nova Scotia, principally of magnetic and specular kinds,—these were exhibited by the side of their manufactured products. The United States of America possesses inexhaustible stores of this metal, and in the form of the best kinds of ore. These deposits are in many instances highly advantageously placed with regard to fuel, vast forests existing in their vicinity, upon which the hand of man can make but little impression for ages to come, and the fuel yielded by which is far better adapted to the production of pure iron than coal. The exhaustless stores of anthracite also facilitate the iron-production of these States. The annual make of iron in the United States is estimated at nearly half a million tons. This quantity is the produce of nearly three hundred furnaces, the half of which use charcoal as fuel. As yet, however, the English iron is produced at a cheaper rate, and conquently supplants the other for many purposes in the market.

Austria possesses great mineral stores of iron, and facilities for its manufacture. Almost all the states of this large empire have considerable deposits of iron ore, and the abundance of wood has rendered its manufacture into metallic iron comparatively easy and economical. The most important iron districts of Austria are Styria, Carinthia, and Lower Austria. The most common ore is the carbonate of iron. The hæmatites are also worked.

France, although much less richly endowed with iron ore and fuel than our own country, has important sources of both these minerals; and these are largely developed at present. The iron ores of France principally abound in the districts of Champagne and Berez. About half a million tons of pig-iron are made annually in France. Some of this is of a good quality; but

other descriptions are poor, and some very brittle. The quality falls generally below that made in England and some other iron-making countries.

The States of the Zollverein, celebrated for their mineral riches in other metals, also possess good deposits of iron ore, which are actively worked, and which yield considerable quantities of metallic iron yearly. The total production of iron in the states of the Zollverein amounts, it is stated, on good authority, to about 150,000 tons per annum.

Still more celebrated than any of the countries just named, is Russia, for the abundance and excellence of its iron ores and manufactures. A most varied and interesting collection of ores and manufactured iron was sent to the Great Exhibition, from the Imperial Foundries and Forges in various parts of the empire. Among other fine specimens of ores, were some obtained from the celebrated magnetic iron ores of Goroblagodatsk.

Sweden and Norway stand, however, preeminently, before all other iron-producing countries, for the admirable quality of the metal sent from their foundries and forges. The iron ores employed are found, on analysis, to consist chiefly of magnetic iron, admixed accidentally with a peculiar ore. The most celebrated mines are those of Dannemora, Utö, Nova, and Phillipstad. The total production is about 133,500 tons annually. The iron possesses an extraordinary, and hitherto unaccountable superiority, to every other for the manufacture of the finest kind of steel, and is for this purpose largely exported. So excellent is the Swedish iron, that even the poorest qualities sent to the Exhibition were considered superior to the best produced in any other country!

Having thus sketched the principal sources of iron, we shall now advert to the manufacture of this im-

portant metal. Let us take, as the most simple and interesting process, that which is to this day practised by the native metallurgists of India, and the product of which has long obtained so high a celebrity through many lands. The following account is an authentic description of this manufacture:—

The furnace in which the iron-stone is smelted is excavated out of the ground, about twelve by ten feet, and ten feet deep; the furnace is made of clay, and plastered with cow-dung heaped. Double bellows, of the shape of leathern bottles, are fitted, air-tight, at the bottom, and are worked by a man sitting between them. At the bottom of the furnace is an earthern sieve, through which the dirt and refuse drop. The holes are filled with earth at first; but this gives way as the iron melts and comes down. When choked, the holes are opened by an iron poker; the drops and dirt then fall. The fire is formed of caked cow-dung, broken small, charcoal, and wood. The wood is put on the top part; a layer of iron-stone, broken to the size of marbles, is then placed about one inch in thickness, then a layer of cow-dung and charcoal, and so up to the surface, when the iron-stone is piled about eighteen inches, and covered in with the wood cut into small billets. After four hours' incessant plying of the bellows, the furnace has attained a heat which makes the first layer of stone melt and the dross fall through: the whole mass has become gradually heated, and as it falls, the stone on the top, which is regularly served, keeps falling into the furnace. In this way the furnace is plied and filled for twelve hours, the bellows going the whole time. The furnace is now left to cool, and, according to the season, is ready to open in from twelve to twenty-four hours.

The iron will amount to about forty pounds' weight or "twenty seers," which, at the pit, including digging the stone, fire-wood, and every charge, sells so that the

profit averages one rupee per seer; the people consequently work only as their wants require, and not regularly.

Nothing more is done by this class of workmen; the iron is sold as it comes out of the furnace, and worked up by another class.

The manufacture of iron in Cutch is thus carried on. In extracting the metal, layers of very small pieces are disposed alternately with others of charcoal, in a rude, open furnace, and exposed to the blast of two small bellows, made of sheep-skins. The metal, when fused, falls into a hole at the bottom of the furnace, when it is transferred to an enclosed furnace, and subjected to similar blasts until brought to a white heat, when it is taken out and beaten into a bar. No flux of any kind is used.

These diminutive furnaces appear to be merely temporary establishments, capable of being moved about from one place to another. By this simple process, "blooms," or lumps of iron of almost 40 lbs. weight, are obtained at one time; and these are then forged into flat bars, from ten to twelve inches long. The quality of the iron is most excellent. The smelting of iron ore is here reduced to its simplest elements, and contrasts remarkably with the complicated and powerful apparatus used for the same purpose in our own and other countries.

Theoretically, the process of iron-smelting appears one of great simplicity. We have merely to take the oxide of the metal and discharge its oxygen, to obtain iron in its metallic condition. Although, as in the process in question, this object can be effected in a very simple manner with the fuel there employed, and with a pure ore, it is rendered more difficult when coal is the fuel used, and the ore contains a considerable percentage of impurities. It will be easily understood, also, that

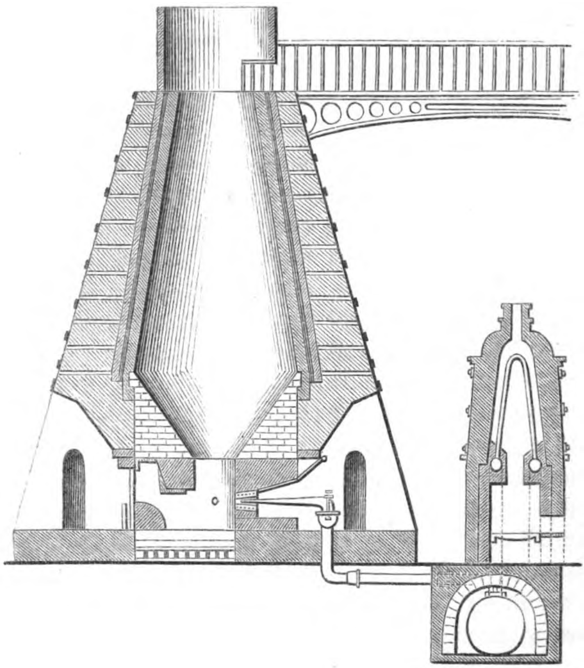
in operating upon a large mass—many tons, for example, of the raw materials—it must be more difficult to obtain a uniform product than when only a few pounds are submitted to the smelting-furnace.

We shall briefly describe this operation from first to last, as it is commonly performed in this country. It is necessary, in treating many kinds of iron ore, that they should be first roasted, in order to expel the water and carbonic acid which may be present in them, and so to reduce the ore to a state more favourable for the smelting process. To effect the calcination of the mineral, it is piled up in long heaps over a stratum formed of coal. The fire is afterwards applied to the windward end of the pile, and, after it has advanced for a certain distance, the pile is prolonged with the same material in the opposite direction. The ordinary height of such a heap varies from six to seven feet, whilst its breadth at the bottom may be about fifteen or twenty feet. When the ore treated, as is not unfrequently the case, contains a large proportion of bituminous matter, it will, when once ignited, readily burn without the addition of any other fuel; but when it is not naturally combined with a sufficient amount of combustible ingredients, its place is supplied by the addition of a sparing mixture of small coal.

Instead of this mode of effecting the calcination of the ore in open heaps, it is in many localities roasted in a sort of furnace or kiln, similar to that employed for burning lime. In this case, if bituminous, the addition of any other fuel to the mineral is unnecessary; but if not in itself combustible, it is interstratified, at certain regular distances, with thin layers either of coal or anthracite.

The ore is now ready to be transferred to the blast-furnace, there to undergo its reduction to the metallic state. This apparatus, which is represented in the

annexed cut, is composed of two truncated cones, made of refractory masonry, which are joined together at their bases. The upper portion, called the body of the furnace, is formed of an interior lining of fire bricks, which is again enveloped in a casing made up of broken scoria, or refractory sand, which separates



the internal lining, or *shirt*, of the furnace from an internal coating of fire bricks, surrounded and supported by a mass of masonry, composed either of stone or ordinary brick-work. The opening at the top of the apparatus is called the throat, or tunnel-hole, and is surmounted by a chimney, in which there are one or

more openings, for the convenience of charging the fuel, ore, and flux, with which the apparatus is at regular intervals supplied. The lower, or inverted cone, is known by the name of the *boshes*, and is either constructed of fire-bricks, or of a very refractory material called fire-stone, found in the mill-stone grit formation.

The lowest division is quadrangular in form, and composed of large slabs of refractory sand-stone cemented together with fire-clay. This part of the furnace is somewhat smaller at the bottom than at the point where it meets the boshes, and its angles are gradually rounded off. This difference of size at the two extremities is, however, in many instances, so small as almost to give to the *hearth* (as this part is called), the form of a quadrangular prism.

The bottom of the hearth consists of a large fire-stone, supported in a mass of masonry, in which are left numerous channels for the escape of any moisture which may be expelled from the brick-work; whilst, to keep the whole building perfectly dry, the foundations are traversed by two large arched galleries, which intersect each other at right angles immediately beneath the axis of the internal cavity of the furnace.

Three sides only of the hearth are continued down to the bottom; the fourth is merely brought to within a certain distance from the base, where it is supported by strong cast-iron bearers, firmly fixed into the masonry of the wall, and on which is placed a heavy block of refractory sand-stone. At a distance of a few inches from this, and a little in advance of it, is fixed the dam-stone, which has a prismatic form, and is secured by a strong piece of cast-iron of peculiar shape, which covers its outer side, and is known by the name of the *dam-plate*. The part of the furnace beneath this is called the *crucible*, and in it is collected the fused metal,

before a sufficient quantity for tapping out has accumulated.

During the process of smelting, the space left between the upper block of stone, or *tympe*, and the dam-plate, is closed by ramming in with an iron bar a small quantity of loam, earth, or fire-clay. The face of the hearth, which is opposite the dam, as well as the other two sides, are perforated a little above the level of the tympe, with holes into which the blast-pipes or tuyères are fitted. These are supplied by means of a blowing-machine, worked either by a water-wheel or steam power.

The manufacturing process is thus conducted:—After the furnace has been carefully prepared for the reception of its charge, by the prolonged ignition of coke, the charge is thrown in at the tunnel-hole, at the top. It consists of coke, iron-ore, and lime-stone, in definite proportions, which are thrown in at regular intervals, and a supply of which is continued with equal regularity so long as the furnace is "in," which may be for a period of two or three years. The blast is then applied, the vast furnace reaches its highest point of ignition, the ore, decomposed by the heat and gaseous elements which surround it, yields up its metallic constituent, which pours down in a molten stream into the crucible. From this part it is discharged when a sufficiency is accumulated, and the burning, fluid metal, is then conducted into the moulds previously prepared for its reception. Day and night this process goes on, until the furnace is at length destroyed or rendered of no further use by the intense combustion so long maintained in its interior.

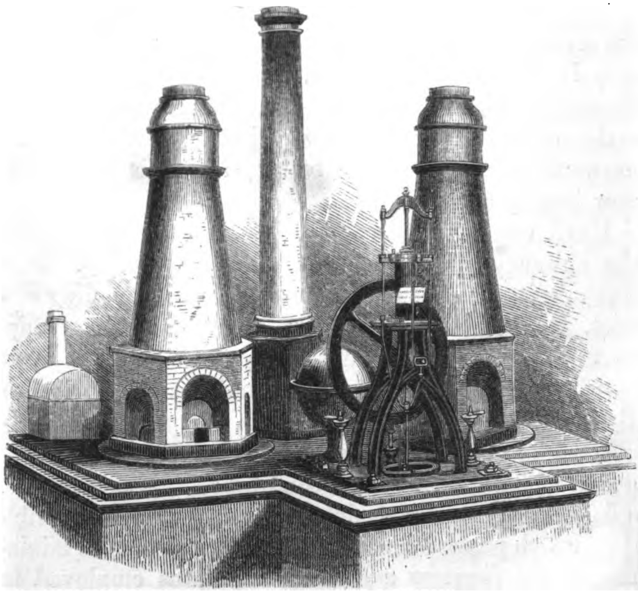
A most interesting and complicated series of chemical decompositions take place in this process, within the gaseous and mineral constituents of the blast-furnace.

Into the discussion of these, however, we have not

space to enter. Its final results are, that from the throat or tunnel of the furnace, combustible and other gases escape, consisting of nitrogen, carbonic oxide, and carbonic acid, hydrogen, and carburetted hydrogen; while, from the opening below, the molten iron flows forth,—not, indeed, in the state of pure metal, but in combination with a certain proportion of carbon. The fluid metal in the tapping of the furnace is directed into a channel called the sow, into which several lateral channels enter, which are called the pigs. When cooled, the whole is broken into its separate parts, and the pig-iron is sent to the markets. For many years the air blown into blast-furnaces was cold, but, by an ingenious series of experiments, it was discovered that hot air answered the purpose far better; and this method is now largely adopted.

Until recently, the combustible gases escaping from the chimneys of blast furnaces were allowed to burn like mimic volcanoes, illuminating the surrounding district. It occurred, however, to a manufacturer to attempt to utilise these gases, and apply the heat they were capable of communicating to some practical purpose. By a very clever and simple plan this was ultimately effected, and the adjoining cut gives a view of the manner in which it has been accomplished. It is a copy of a daguerreotype of a model shown at the Great Exhibition, which possessed a beautiful representation in miniature of the furnaces and other apparatus employed in the manufacture of iron at the Ebbw Vale Works, near Abergavenny, in South Wales. At this establishment, the gases evolved from the furnaces—and which, from the amount of hydrogen, carburetted hydrogen, and carbonic oxide gases which they contain, are highly inflammable, and capable of developing a considerable degree of heat by their combustion—are conducted by proper pipes and channels to the various places where

heat is required; and, being there ignited, with a due admixture of atmospheric air, they afford a fuel by the use of which the amount of solid combustible employed is considerably diminished. The model exhibited not only afforded an illustration of the way in which these gases are applied to the generation of steam for the blowing engine, but also showed the details of the arrangement by which, at the Ebbw Vale Works, the



same agent is made to supply the amount of caloric necessary to heat the blast forced into the apparatus to the temperature of about 600° Fahrenheit—which is that at which the air furnished to hot blast furnaces is commonly supplied. The model further showed the blowing machine itself and the engine by which it is set in motion, together with its various appurtenances, such as

a large air vessel for regulating the blast, and the tuyères and nozzles by which it is admitted into the hearth.

In order to facilitate the process of drawing off the waste gases, with a view to their subsequent employment for heating purposes, a closed-top furnace, of which a model was also shown, has been invented by Mr. J. James, of Abergavenny. Until, however, its efficiency for the intended object has been proved by a practical trial, there will exist some doubt as to the success likely to attend the use of this contrivance; as the ring forming the valve would not only be liable to get so twisted by the heat as to become fixed, but it has hitherto been found very difficult to keep a furnace in a good state of working when more than about one-third of the escaping gases has been diverted from its usual course.

Iron is employed in the arts in three conditions. First, in that of cast-iron; second, in that of wrought-iron; and, third, in that of steel. The first and third of these substances consist of iron combined with carbon; in cast-iron with more than in steel. Wrought-iron is the metal nominally without combined carbon, but it is rarely obtained in practice so pure as to be absolutely devoid of a small proportion of carbon. When the molten stream of iron comes from the furnace it is not in a state fit for the forger or for the maker of steel. For this purpose it requires to be refined—that is, to have its carbon burnt away in a furnace called a finery, and still further, in the process technically called puddling. Intense heat and atmospheric air form the means by which the superfluous carbon is discharged, and the iron left in a comparatively pure state.

The further progress of the metal is simple enough. It is submitted, while yet incandescent, to the operation of enormous hammers, which knead it into a tenacious mass. This is then taken to rolling machines, which reduce it to the requisite size and shape, whether of bars

or sheets. For the production of steel a still further series of processes becomes necessary. Bars of the best iron are selected for this purpose, and are placed in troughs made of firestone, in which they are surrounded with pounded charcoal; these are then heated, and in time combination of the carbon and of the iron ensues, forming steel. The bars are then submitted to the tilt-hammer, which reduces them to a homogeneous structure and convenient shape. Cast steel is produced by melting the bars of blistered steel in crucibles of fire-clay, and then pouring the fluid metal into ingot moulds.

Among the interesting specimens of skill shown at the Great Exhibition in the manufacture of this metal, were some which deserve special notice. A Council medal was awarded to one of the Austrian exhibitors, the Baron Von Kleist, for the extraordinary excellence of the sheet iron produced at his works. Those who were familiar with all the processes of the iron manufacture were surprised at a particular kind of sheet iron made at these works, and appropriately called iron paper, a title completely justified by its qualities. It was extremely thin, flexible as paper, strong, and free from flaws. It was used for making buttons and stamped articles, and was capable of taking a high polish after being worked. Very shortly after this iron paper was exhibited some English manufacturers attempted to imitate it, and before the Exhibition closed they succeeded, and we inspected an iron book made out of this thin sheet. This was one of the excellent results of the Exhibition, in its bearings upon the advancement of our manufacturing skill. It has been proposed to use this material for public works in those colonies where the ants commit such ravages upon paper and parchment books.

Specimens of iron twisted violently when cold, and partially broken to show the fibrous fracture, were

shown by many exhibitors. Among the more striking objects of manufactured iron were some specimens of bars and drawn tubes. From the works of Messrs. Bagnall, at West Bromwich, a round bar of iron was sent which was probably the largest ever produced. It was twenty feet one inch long, seven inches in diameter, and weighed one ton and three quarters. The other was a cylindrical iron tube, twelve feet long, and seven inches in diameter, which was drawn by a patent process at the works of Messrs. Selby and Johns, of Smethwick. Several immense railway bars were also exhibited.

A Council medal was awarded for the manufacture of steel to a Prussian exhibitor, whose specimens attracted universal admiration. It would seem that this exhibitor pursues a method of manufacturing steel differing from that practised in other countries. The great size of the objects he exhibited drew the attention of manufacturers to them. Special mention deserves to be made of a fine pair of cylinders for rolling steel; of a rough cylinder, nearly four feet long, and weighing 4,300 lbs.; the axle of a railway carriage, weighing 100 lbs.; and a cylinder, fifteen inches in diameter, broken across the middle. This last was a magnificent specimen of skilful metallurgy, and exhibited a remarkable fineness and evenness of grain throughout. The members of the jury publicly stated that they had never met with such a specimen of steel before.

Our Sheffield steel producers were also well represented by their specimens. A large manufacturing firm sent a series of models of the converting furnaces and other arrangements for the production of blistered and of cast steel, large ingots of which were also shown. Of these, one weighed 6 cwt. 3 qrs. 18 lbs.; the other weighed 2,688 lbs. It was five feet eleven inches long, and nearly fourteen inches in diameter. The total

quantity of steel produced at Sheffield is estimated at 35,000 tons annually.

A substance more remarkably distinguished for its peculiar physical properties than its industrial value, was the *iron sponge* of a French exhibitor, M. Chenot. This manufacturer has attempted to obtain pure iron from the ore without passing through the state of pig. To effect this, it is deoxidised in a closed vessel at a dull red heat, by a reducing gas, and the result is, that a porous mass of iron is obtained, somewhat resembling a sponge in its characters. As yet this substance has not been found capable of being forged into a homogeneous mass. It is remarkable, however, that it burns with flame, like any other combustible substance, on being merely lighted with an ordinary match, the iron being in a state of very fine division, and being reduced to an oxide after combustion.

The place of next importance in our study of the metals and their ores must be given to Copper. This valuable metal occurs naturally in a pure condition, but it is, for the most part, obtained from its ores. Native malleable copper is most frequently met with in irregularly-shaped masses, occupying the fissures of the rocks in which it is found. It generally takes the form of these fissures, exhibiting the impressions of the surface with extreme accuracy. It is found in the Cornish, Brazilian, and Siberian mines. But the most splendid specimens of native copper have been obtained from mines in the United States of America, a little to the north of Lake Superior, whence masses of nearly pure metal, exceeding a ton in weight, have sometimes been extracted. When found in this state it appears to be a result of a species of natural electrotype process on a great scale. At the Great Exhibition there was shown a piece of native copper from these mines, weighing 2,544 lbs.

The sulphurets of copper constitute its most import-

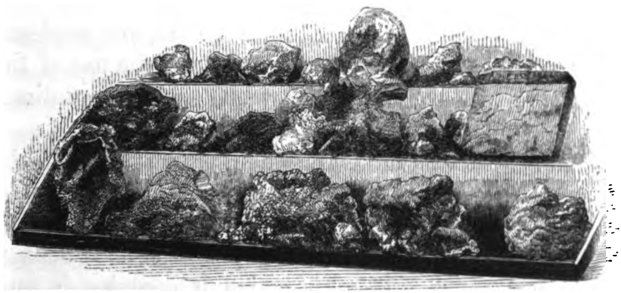
ant and abundant ores. To this class belongs copper pyrites, or yellow copper ore, which is distinguished by its strong metallic lustre, and deep brass-yellow colour. It usually occurs in amorphous masses, with an irregular and slightly conchoidal fracture; it is also found in mammilated, stalactitic and botryoidal forms, as well as in tetrahedral and octahedral crystals. It is, chemically speaking, a double sulphuret of copper and iron, and consists of one equivalent of sulphuret of copper, united to one atom of protosulphuret of iron. This mineral, which is by far the most abundant of the ores of copper, is found in lodes or veins which usually occur either in granite, greywacke, or clay slate, although it is sometimes met with in serpentine, gneiss, and some other rocks. In these deposits it is most commonly associated with iron pyrites, blende, and galena, together with the carbonate and other ores of copper.

Grey copper ore, which is likewise an extremely valuable and very extensive source of copper, usually occurs in a massive form, although it is more rarely found crystallized in tolerably well-defined cubes and octahedrons. Its colour varies from steel grey to iron black, and, when scratched, it yields either an unchanged or slightly brown streak. This substance is a compound sulphuret, in which the metals associated with the copper may vary very considerably, both in their relative amounts, and also in their nature; but iron, antimony, zinc, and silver are amongst those most commonly contained in grey copper ores. This mineral generally exists in greater or less amounts in most of the copper-producing districts, and, from the quantity of silver which it frequently contains, is often treated as an ore of that metal.

In addition to these ores, the oxides and the carbonates of copper also constitute valuable sources of the metal. The green carbonate or malachite was splen-

didly illustrated at the Great Exhibition in the gorgeous furniture, vases, doors, and objects of art made from it. This very beautiful copper ore has long been valued for ornamental purposes, and, till the discovery of similar ore to a large extent in South Australia, was almost exclusively obtained from Russia. The richest and finest masses of malachite seem to have occurred about 100 miles south of Bogoslovsk, but amongst similar igneous and altered rock to that of Frolovsk, where also there is a considerable quantity. The malachite occurs in openings between a garnet rock and limestone, and exists generally in masses. The mineral itself has every appearance of having been formed by a cupriferous solution depositing its residue in a stalagmitic form, exactly as is known to occur with carbonate of lime in caverns. The external surface of the concretions is frequently covered with a black oxide of manganese, which falls off when touched. To give some idea of the magnitude of such masses as have been found in Russia, we may refer to the account of a lump discovered at Nijne Taghilsk, a few years ago, at a depth of 280 feet. Sir R. Murchison thus describes it:—"Thin strings of green copper ore occurring at intervals were followed downwards, when, increasing in width and value, they were found to terminate at the base of the present mines, in an immense irregularly-shaped botryoidal mass of solid malachite, the base of which had not been traced." The summit of this mass is described as being eighteen feet long and nine feet wide, and the whole of the surface uncovered at the time of the visit of our countryman in 1843, was calculated to contain not less than half a million of pounds weight of pure and solid malachite. Those portions of this copper ore, which are not adapted for the purpose of ornament, are highly valued for the copper which they contain, and are treated by the smelter as the ordinary ores of this metal.

The ores sent from various districts and countries to the Great Exhibition proved an interesting representation of the diffusion of this valuable metal over the globe. Beautiful specimens were sent from the Cornish copper mines, also from some Irish and Scotch mines. The collection, however, sent by the owners of the Burra Burra mines—which is shown in the cut—was superior to many of the others. It comprised native malleable copper, finely crystallized, red oxide, and some specimens of malachite, quite equalling those sent from Russia.



The treatment of these ores, and the extraction of the metal next demand our attention. These processes were very clearly illustrated on the great occasion referred to by a set of models which showed the apparatus used at the Tywarnhale mines, the property of the Prince of Wales. The copper ore raised at these mines is so poor, that it would not pay for the working but for the ingenious methods adopted to extract the metal by this apparatus. The following brief description of these models shows the stages through which the ore passes. The first apparatus is the crushing mill, which pulverises the ore, and more effectually than the common stamping mills. From this it enters a reservoir for receiving the pulverised mineral, and passes from it, by the action

of a stream of water, to the shaking trunk. Here the mineral is separated into proper sizes, for the subsequent processes, by means of a revolving cylindrical sieve, instead of the ordinary process of shaking or stirring it with shovels in a stream of water. All the ore does not pass, and this is then put into a machine called a tye, used for cleaning the rough grain ore which does not pass through the cylindrical sieve, and preparing for sale part of the ore which settles at the head. Next is what is called a double lever jigging machine, for dressing the poorer portion of the mineral from the tye, technically called the "tails:" by a single operation of this machine, the earthy matter is separated from the ore, and rendered fit for sale. With some qualities of ore, the use of the tye is dispensed with, and the rough grain comes direct from the shaking sieve to the jigging machine.

The fine-grained mineral, which passes through the sieve and settles in the shaking-trunk requires to be cleaned, and this is effected by passing it into a simple apparatus called a round buddle, where it is shaken about with water. The ore which it contains is rendered fit for sale by being twice buddled.

The next portion of the works is the slime pit, for receiving those portions of the mineral which are reduced to so fine a powder as to be carried away, in the shaking and other processes, by the stream of water. In connexion with this pit are a set of self-acting trunks, for removing a large proportion of the earthy matter contained in the slimes; when thus concentrated, the slime ore is rendered fit for sale, by being twice buddled, as before.

This mode of working the poorer copper ores is essentially similar to that adopted for the richer kinds, differing only in the greater care taken to remove the impurities, and to obtain the ore in a finely divided state as free from other minerals as possible. The

richer ores do not of course require so much washing and other preparation to fit them for sale as the poorer kinds.

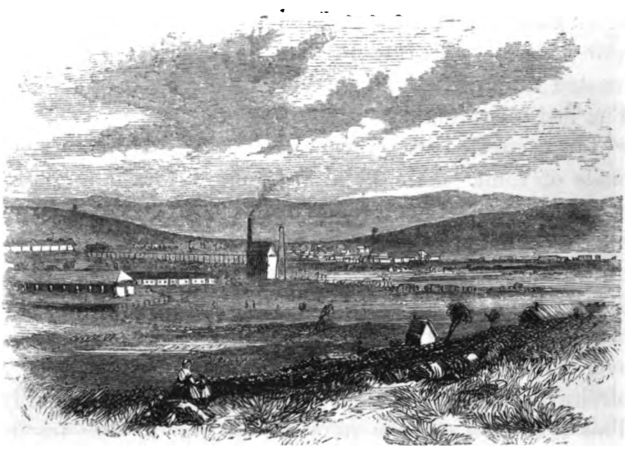
The next process is the manufacture of metallic copper from its ores. This is chiefly carried in South Wales, where there is an abundant and cheap supply of the fuel necessary for this purpose. The ores are first roasted in reverberatory furnaces to get rid of the arsenic and sulphur which they contain. After this the ore is submitted to an intense heat so as to melt its metallic constituents. And in order to purify it as far as possible, it is allowed to flow in a liquid state into water, by which it becomes granulated. It is then again calcined, and again melted. The melted metal is now generally run into moulds or pigs, these are then roasted and melted again, and again run into moulds. The last operation consists in the refining of the pigs, which is effected in a furnace, the bottom of which is made of sand. The metal now runs into a hollow near the door of the furnace, and when deemed sufficiently fine, it undergoes the interesting process of toughening, by which it is rendered malleable and fit for the purposes to which this metal is applied. The toughening process is effected by spreading a quantity of charcoal over the melted metal, and then plunging a pole of birchwood into it, which makes it boil up violently. This is carried on, the refiner from time to time testing the state of the metal by taking out specimens, until at length the copper loses its brittleness, and assumes a close and fibrous texture. In this state it is finished, and is then poured into moulds to form ingots for the market.

The smelting processes, though apparently complicated, are really very simple, having for their object the destruction by means of heat and the oxygen of the air, of the arsenic, sulphur and iron which the ore con-

tains. The gaseous products of the smelting processes are generally condensed by water, since their emission into the atmosphere proves very injurious both to vegetable and animal existence. The produce of the copper mines of Cornwall in 1850 amounted to 155,025 tons of ore, yielding 12,254 tons of metal, the value of which was 840,410*l.*

The Burra Burra mines, represented in the cut, form a remarkable feature in the history of this metal, and have thus been adverted to by Mr. Robert Hunt:—

"The Burra Burra mines present one of the most striking examples of successful mining speculation with

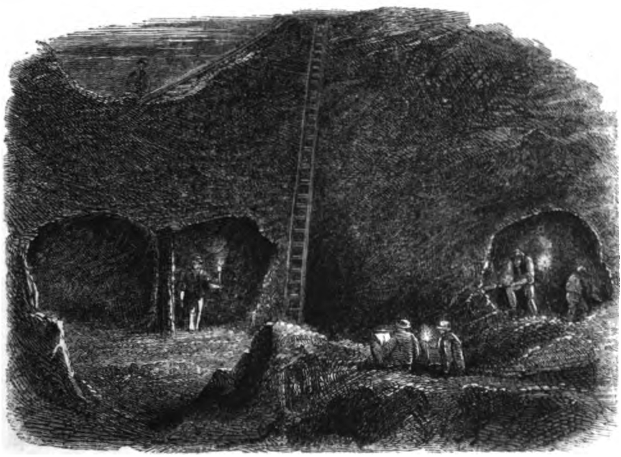


which we are acquainted. From indications which were regarded as of a most favourable character, the mine was started on the 5th of September, 1845, with a capital of 12,320*l.*, subscribed by a few merchants and traders at Adelaide. The following returns of ore raised from the commencement of the undertaking to September, 1850, will exhibit the extraordinary success of this undertaking:—

		Tons.	Cwts.
September 30, 1846	. . . . .	6,359	10
" 1847	. . . . .	10,794	17
" 1848	. . . . .	12,791	11
" 1849	. . . . .	7,789	16
" 1850	. . . . .	18,692	9
Making a total in 5 years of	.	56,428	3

of copper ore, varying in quality from ore containing 30 per cent. of copper to much that produces 70 per cent. of that metal. The money value of this is 738,108*l.*

"This great mineral deposit exhibits some peculiarities. Although the miners and the proprietors



speak of working on lodes, these are of a very different character from the copper lodes of the primary rocks of this country. In a great basin, formed in an amphitheatre of hills, an immense deposit of clay—the result of the decomposition of the clay-slate—has taken place; this, under conditions which we are not enabled to determine, became also the reservoir for the reception

of copper. In all probability it was first deposited in the pure metallic state—a fine example of the electrotype process of Nature. During this process, the so-called veins spread themselves through the soft clay in various directions, in precisely the same manner as we may, by carrying the terminal wires of a voltaic battery into a mass of clay saturated with sulphate of copper, form a curious arborescent mass. By the action of the oxygen contained in the water, this copper becomes oxidized by the slow process which gives rise to the very beautiful crystals of red oxide of copper, and from this state it passes into the blue and green carbonates, under the action of carbonic acid; the difference in the colour of the two arising from the quantity of water in combination.

"The malachites, which are now very extensively employed for ornamental purposes, are carbonates of copper, and large quantities of the specimens selected from the Burra Burra mines are sold for this purpose."

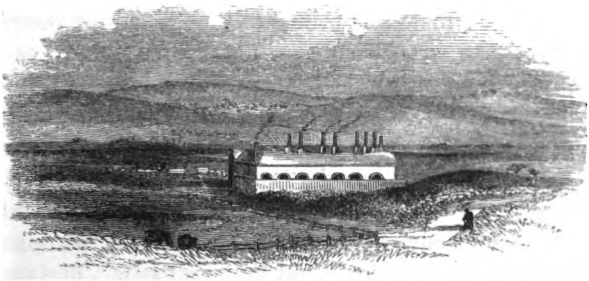
The cut on the last page represents the manner of working the Burra Burra lodes.

"The number of people now employed at the Burra Burra mines is 1,003."

Formerly all the copper ores raised in Australia were sent to this country to be smelted; but now smelting-houses are at work at the Burra Burra and other mines, and a view of these works is given in the cut. This and the other views were copied by photography from well executed water-colour drawings sent from Australia to the Great Exhibition, as illustrations of its copper-mining industry.

Several other methods of obtaining metallic copper are practised, and were illustrated on the occasion referred to. Of these we shall only mention that of Mr. Longmaid, which was rewarded with a Council

medal for its ingenuity and industrial value. It is not merely a process for obtaining copper from its ores, but also for procuring by a series of ingenious combinations of the substances employed, a variety of other results. A great number of these were shown at the Exhibition, but it is not necessary to investigate them. The following is a simple explanation of the essential details of this process :—Copper pyrites (the double *sulphuret of copper and iron*) is combined with salt (*chloride of sodium*), and roasted at a certain moderate temperature. By this, a double decomposition is effected. Sulphate of soda is produced by the combination of the sulphur



of the ore with oxygen, to form, first, sulphuric acid, which then unites with soda from the chloride of sodium. The copper is converted into a soluble sulphate, the iron being left in a state of per-oxidation, and the chlorine liberated, which is employed in the manufacture of bleaching powder. The copper may then be obtained in a metallic state from the solution of the sulphate by putting pieces of old iron into it, which precipitates the copper,—sulphate of iron being at the same time formed. The importance of being able to dispense with the use of sulphuric acid in the preparation of carbonate of soda for decomposing the common salt used in that process, and the utilisation

of the chlorine liberated so as to form bleaching powder, constitute the leading valuable features of this process, and render it likely to be of greater service to the chemical manufacturer than to the metallurgist.

Another process was also exhibited, and attracted some attention by the splendid crystals exhibited from the works, which is actively carried on under a patent at the Red Jacket Works, near Swansea. Sulphate of copper is obtained by oxidizing copper pyrites, and dissolving out the sulphate formed. Metallic copper is precipitated from this by pieces of iron.

Next to copper and iron in industrial importance may be placed the valuable metals Lead, Tin and Zinc. The first of these metals is principally obtained for the purposes of the arts from the natural sulphuret called galena. This mineral is heavy, and lead-like in its colour, but has a peculiarly brilliant crystalline lustre. The extraction of the ore is a work of much labour in consequence of the density of the rock in which it is imbedded. But it does not essentially differ from other mining operations, being carried on chiefly by the aid of gunpowder and the usual miner's tools. The treatment of the ore when it comes to the surface we have carefully examined among the Welsh mines, and can therefore give testimony in favour of the accuracy of the following account, which is derived from a visit to these mines, published in one of the daily papers in 1851:—

"Descending a cleft of the mountain, through woods and enclosures, we at length reached the mouth of the mine. I found it of much the same character as other lead mines which in various localities I had passed. They are generally situated on a steep declivity, and have shallow platforms cut away, stage above stage, for washing and dressing the ore, with a lofty but narrow water-wheel (sometimes more than one), to which a clear, rushing, and noisy stream descends, led round

the face of the mountain to the wheels, the jiggers, and the washing pools. At the Gorn Mine, the large water-wheel is under cover. At this and most other lead mines there is little of the noise and bustle which abound at the coal and iron mines of South Wales. The ores here, when prepared, occupy relatively but a small space, and being removed in carts and waggons, the clanking of numerous trains on a railway, with the shrieking and puffing of locomotives, is entirely unknown. The work goes quietly forward; the only sounds are the rolling of ore over the ore stages, the musical beats of the great wheel as the water tumbles over each successive bucket, and the short rattle of the jiggers for screening the ore, the reverberations of which do not disturb the hare that squats in the oak wood over the mine, or the red squirrel that gambols in the trees.

"When cut by the miners, the ores are wheeled or carried to points convenient for loading and removal. They are next placed in narrow iron trams containing each about 25 cwt., and hauled by donkeys out of the mine to the first stage or terrace of the dressing-floors. Here the trams are canted over, and the work commences. At the Gorn Mine, now under notice, there are several dressing-floors, cut in the left bank of the ravine, and descending by successive steps downwards. Through these, a stream of water is conveyed for the purpose of washing the ores.

"Commencing with the first process, the following is a description of the operations. Standing upon a wooden platform, a lad of sixteen, fenced about with sacking to protect himself from splashings, draws the lumps of ore by means of a rake, from the heap deposited by the trams, under and through a smart stream of running water falling from a spout, down to the stage on which he stands. The effects of the water upon these

masses is, by washing off the clay and impurities, to display the dark blue veins of lead interspersed through the stone. A number of boys, by means of short iron hooks, then drag these lumps over an iron grating, through which any fragments of the lead ore which, by this process, may be disintegrated fall, and are carried into a trough overflowing with water. The large pieces of rock, which contain no particles of the mineral, are thrown into barrows and wheeled away. The lumps of ore considered too large for passing through the 'crushers' are next picked out, set aside, and broken with hammers—in the ordinary way of breaking stone—by girls and boys. When reduced to a convenient size, the broken ores, and the fragments deposited in the trough, are from time to time carried to the crushers.

"We next come to the operation of crushing the ores. For this purpose an apparatus, consisting of a pair of large iron cylinders, put in motion by an overshot waterwheel of some twenty feet diameter, is employed. This operation is carried on in a building of two stories, the upper floor being on a level with the stage where the ore is broken. When I entered the 'crushing-house' a girl was feeding the machine. She placed the broken ore, as brought to her by the boys, in a hopper leading to the cylinders, through which it passed to the lower room, where, for convenience sake, we will follow it. After going through the cylinders, which are weighted so as to accommodate the strain of any unusually large or hard fragment, the ore falls into a revolving wire sieve leading diagonally from the cylinders to a bucketed wheel of some twelve feet diameter, revolving at a short distance off. The effect of this is, that the ore, reduced to the size of coarse sand, passes through the upper part of the sieve into a stream of rushing water, and is carried into a small pool or trough, while the unbroken lumps and 'gravel ore'

fall from the lower end of the sieve into the bucketed wheel, which carries them back to the upper floor, and deposits them near the hopper. The girl then passes them a second time through the cylinders, and this process goes forward simultaneously with the feeding of the machine with new ores, so that very little passes into the water larger than is convenient for the purpose of washing. The ore, which we have seen pass through the sieve to the water-trough, is stirred freely about by a boy using a shovel, so as to wash away as much as possible of the comminuted quartz, spar, and other impurities, with which it is intermixed. This boy now and then throws aside a few shovels-full of the ore for the women, who carry it to the 'jiggers.' The latter are cradles of wood (suspended from uprights) having sieve-bottoms of iron wire. They are worked by means of lever handles in a square deep trough of water. Women are employed for this duty. They take a quantity of the crushed ore, and place it in the 'jigger,' which at that time stands above the surface of the water in the trough. Seizing the lever-handle, they raise it, and the jigger cradle descends into the water. This done, the women press the lever handle against their knees, and move oddly on tiptoe up and down, making a monotonous and peculiar rattling sound with the framework. By this motion (the water flowing meanwhile rapidly through the sieve-cradles) the finest particles of the ores are carried through the wires, and by their gravity sink rapidly and accumulate in the bottom of the trough; while the rubbish and coarse matter accumulate on the surface of the mass in the jigger-sieve, whence it is dexterously skimmed off, and returned to the 'crushers,' or put through the washing pools, as circumstances require. The jigger-troughs are emptied of the pulverised ore twice a-week: each contains several hundredweight of ore.

"We now come to the washing pools. These, as I have said, are situated one below the other—a spout of some twelve to eighteen inches diameter conveying a stream of water successively through them. The ores, reduced to the size of sand by the process of crushing, are here exposed to the current of water, being continually stirred by a man with a kind of hoe, called a 'corluck.' This operation requires much judgment and experience;—the workman, by a dexterous turn of the wrist, throwing the ores from the corluck in a semicircular line like the opening of a fan, so that every particle is fully exposed to the action of the water. The specific gravity of the lead causes it to sink rapidly, while the crushed stone and spar, being lighter, are washed away. The lead is next raked on one side, to be taken to the storehouse. But a portion of the finest-grained ore escapes by force of the current of water; hence it is necessary that the operation should be repeated in the pool below. This is done in the very same manner at three successive stages, till all the lead is removed, and the water flows off turbid and milky, carrying away nothing but the impurities."

The production of metallic lead from the galena will appear a simple process when it is stated, that, by merely exposing the galena to a sufficient heat, its sulphur passes off as sulphurous acid, and metallic lead runs out. The smelting furnace in which this operation is carried on is of the reverberatory kind, and the ore, having been put into it at a moderate heat, so as to oxidate the lead, is gradually exposed to a more intense heat, by which the remaining sulphuret becomes decomposed, and both the oxide and sulphuret give up their metallic constituent, which flows out in a remarkably pure condition.

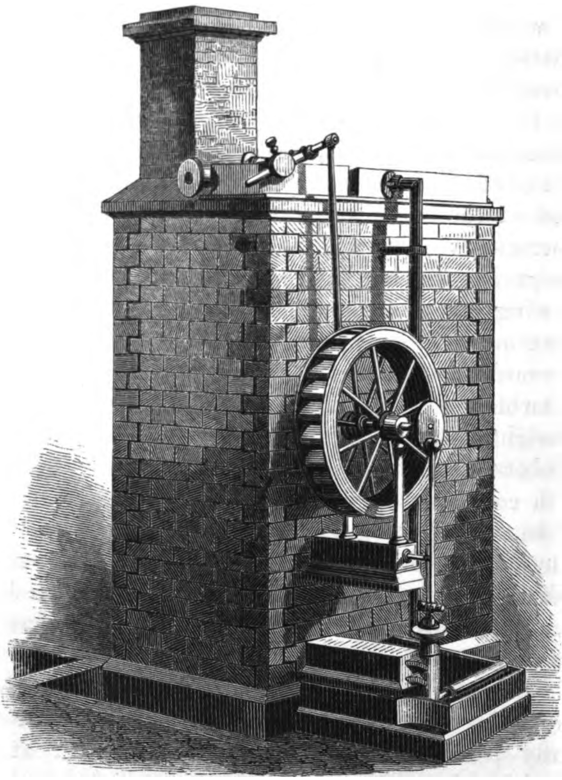
The intense heat, however, employed for the production of this metal causes a portion of it to become

volatile, and escape in the form of fumes, which, on escaping into the atmosphere, fill it with a deadly poison, which injures vegetable and animal life for a considerable distance around the smelting works. On this account, these establishments are often situated in wild and desolate places, where land is of little value, and where their noxious effects cannot influence the habitations of man. In order to obviate this great inconvenience, various arrangements have been adopted, from time to time, with more or less success. Among the most useful of these, has been the interesting contrivance adopted by the Duke of Buccleugh, and illustrated at the Great Exhibition by an extremely well-constructed working model. This is represented from a photographic original in the cut in the next page. The following is the Catalogue account of this ingenious arrangement, which was rewarded by the jury with a prize medal:—

"An oblong building in solid masonry, about thirty feet in height, is divided, by a partition wall, into two chambers, having a tall chimney or tower adjoining, which communicates with one of the chambers at the bottom. The smoke from the various furnaces, eight in number, and about 100 yards distance from the condenser, is carried by separate flues into a large chamber, from thence by a larger flue, it enters the first chamber of the condenser at the very bottom, and is forced upwards in a zigzag course towards the top, passing four times through a shower of water constantly percolating from a pierced reservoir at the summit of the tower. The smoke is again compelled to filter a fifth time, through a cube of coke some two feet square, through which a stream of water filters downwards, and which is confined to its proper limits by a vertical grating of wood.

"The smoke having reached the top, is now opposite

the passage into the second, or vacuum chamber. This is termed the exhausting chamber, and is about five feet by seven feet inside, and thirty or more feet in height. On its summit is fixed a large reservoir, supplied by an ample stream of water, always maintaining a depth of



six to ten inches. The bottom of this tank is of iron, having several openings, or slots, twelve in number, about an inch in width, and extending across the whole area of the reservoir, communicating directly with the chamber beneath. On this iron plate works a hydraulic

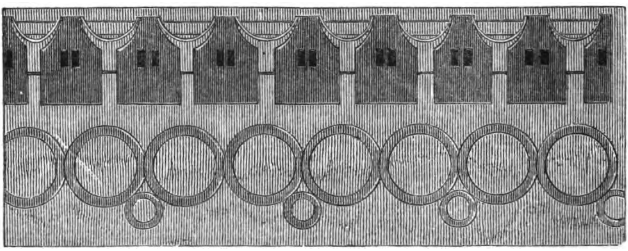
slide-plate, with openings corresponding in one position with those in the reservoir. This plate receives a horizontal reciprocating motion from a waterwheel or other power, driven by means of a connecting-rod and crank. In the middle of every stroke, the openings in the place correspond with those in the bottom of the reservoir, and a powerful body of water falls as a shower-bath the whole height of the vacuum chamber, and in doing so sweeps the entire inside area, carrying with it every particle of insoluble matter held suspended in the vapours coming from the furnaces.

"The atmospheric pressure, of course, acts in alternate strokes as a blast at the furnace-mouths, and causes a draught sufficiently strong to force the impure vapours through the various channels, in connexion with the water, the wet coke, and exhausting chamber, until it passes, purified and inert, into the open atmosphere. The water, saturated with particles of lead, &c., held in mechanical solution, finally passes into great dykes or reservoirs, excavated for the purpose; and then deposits at leisure its rich charge of metal."

The results of this arrrangement are most apparent, and beneficial to the surrounding neighbourhood. The noxious fumes which formerly escaped from these furnaces destroyed all surrounding vegetation, and rendered the vicinity barren and deserted. At present the aspect of the scene has entirely altered; vegetation has recovered its former luxuriance, and sheep graze close to the works. In addition to this, the deposit of lead formerly wasted is now, in a great measure, recovered.

A still more important invention connected with the lead manufacture is the process of removing the silver, which always is found associated with this metal in variable quantities. Some ores of lead contain a very large proportion of silver, while others contain so little that, until the discovery to which we are about to

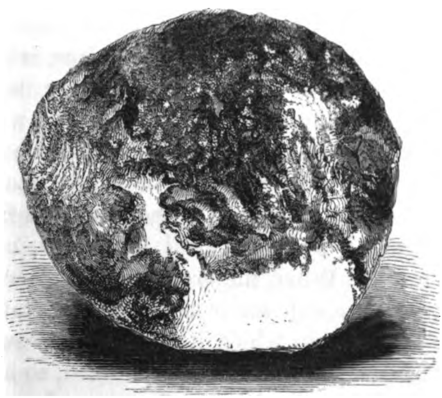
allude was made, it was not thought worth while extracting it. The silver can be removed by oxidating the lead in a refining furnace, to which a blast of air is connected. The oxide of lead is blown away as fast as generated, and at last pure silver alone remains behind. But few ores of lead were remuneratively treated on this plan. Mr. Pattinson, ingeniously availing himself of the property of metals to crystallize at different temperatures on cooling, adopted this as a method for removing the silver from its associated lead. He found that on cooling some lead containing silver, the alloy of silver and lead remained fluid at the bottom of the melting pot, while the lead crystallized and might be lifted out by metal strainers, leaving the silver alloy behind. This plan he carried into practice, and essentially it is now adopted almost universally. The accompanying diagram represents the series of melting-



pots into which the lead is put successively. The lead becomes progressively more and more rich in silver as it is melted, cooled, and strained, until at last a quantity of lead is obtained extremely rich. This is then refined, the lead is oxidated, and a splendid cake of silver, presenting the appearance in the cut, remains to repay the smelter for his trouble in its separation.

The whole of the details of this process were very beautifully illustrated at the Great Exhibition by many

exhibitors. The iron strainers used to agitate the melted lead and strain off the crystals, the lead in all its stages of progress, some exhibiting beautiful iridescent colours, and the resulting silver were all shown in the most interesting and instructive manner. Several large cakes of silver thus obtained were exhibited, but the largest was one which weighed 8,000 oz., and was obtained at the lead-smelting works of Mr. Beaumont, in Durham. The chief illustrations of this metal, both in the ore and manufactured state, were British. But there were also sent specimens from Belgium, from



Spain, Tuscany, and the Zollverein. The Jury recognised the skill of one manufacturer in lead, by awarding him a prize medal, for the excellence of his lead tubes. A specimen sent was 1,800 feet long, and perfectly cylindrical in the bore throughout. A French exhibitor also showed some good illustrations of the flexibility and ductility of this soft metal, in what he called spun lead; being, in fact, lead wire and tape of extreme tenuity.

The important metal, Tin, is the next of our series. The ore from which it is obtained is found in the crystalline rocks, granite, gneiss, and mica slate. Cornwall

is one of the most productive localities as regards this substance, which is also found in Saxony, at Altenberg, Geyer, Ehrenfriedersdorf, and Trinuswald; in Austria, at Schlackenwald, and other places; also in Malacca, Pegu, China, and the island of Banca, in the East Indies. It also occurs in Gallicia, in Spain; at Dalecaria, in Sweden; in Russia, Mexico, Brazil, and Chili; and likewise at Chesterfield and Goshen, in the United States of America. The principal tin mines now worked are those of Cornwall, Banca, Malacca, Saxony, and Austria. Some of the Cornish mines appear to have been worked for this mineral long prior to the Christian era.

The ore, on being brought to the surface, is submitted to the first of those operations necessary in order to separate the metal from the impurities with which it is associated. It is first washed in running water, and afterwards broken into pieces of moderate size. These are then carefully picked. The metalliferous fragments are then crushed by a powerful apparatus, called the stamping mills. When the ore is pounded sufficiently fine, it passes through an iron sieve-like grating, into a series of cisterns, in which it is allowed to subside.

These cisterns are ingeniously arranged, so as to form a succession of receptacles for the ore. Into the first of the series the larger and coarser particles fall, by their own weight; into the second, a size of particles rather smaller, and so on to the last, which contains the very finest mud. The pounded ore is then removed from these reservoirs to undergo a series of washings and shakings, on the completion of which it is again allowed to subside according to its density in a series of pits. On being taken out of these pits, it is obtained in a state of comparative purity. In this state tin ore is still found to contain certain ingredients, the presence of which, even in small quantities, is injurious

to its quality. These are wolfram or tungstate of iron, and iron and arsenical pyrites. In order to remove these (a mechanical process being rendered useless by their respective densities being nearly the same), the ore is roasted in a reverberatory furnace. By this means, the sulphur and arsenic are driven off, but the wolfram and the iron remain. The iron, which is now in a state of oxide, and therefore lighter than the tin ore, is easily removed by washing in the water, which leaves the tin ore behind. The separation of the wolfram or tungstate of iron is a more difficult process. This has, however, been well acccomplished by Mr. Oxland, who exhibited his process at the Great Exhibition. The ore is roasted with carbonate or sulphate of soda, and the process is so conducted that the tungstic acid leaves the iron and combines with the soda, thus decomposing the wolfram; and tungstate of soda being formed, the tin ore, commonly called black tin, is then fitted for further treatment in the smelting-house.

The next process is that of smelting. This is generally effected in a reverberatory furnace. The ore is mixed with powdered anthracite, and a little lime, to act as a flux. The heat is then progressively raised, and continued until the metal is obtained in a liquid state, and lies in a glittering pool within the furnace. The scoriæ are then raked away, and a hole being made for the exit of the tin, it is allowed to flow out into a receptacle fitted for it, and where it remains for some time, so that it may become completely separated from the liquid slags with which it may still be contaminated. These are skimmed off, and the tin is ladled out into ingot moulds. The metal thus obtained has then to be refined. This is effected in the same way as the refining of copper, by means of green wood, and stirring the metal with poles, until its impurities are

removed as far as possible by this process. The tin is then allowed to cool, and in cooling it separates into two or three strata. The two upper of these layers are tolerably pure, and are sent to market. The lower contains much of the foreign metals, and is again refined.

In 1850, 10,052 tons of tin ore were raised in Cornwall and Devon, the value of which was about half a million sterling. Tin is, however, imported, especially from Banca, to the extent of nearly 1,800 tons. At the Great Exhibition, an excellent collection of tin ores, of apparatus for dressing, and of the metal in its various states, was shown. The Cornish exhibitors sent a series of specimens, which received the award of a medal from the Juries. Among other specimens shown, was an ingot of tin, the great antiquity of which remarkable. This ingot was found in a Cornish mine, and is supposed to have been melted by the Phenicians, at the time when they were in the habit ot trading to Cornwall for this metal. Tin was also exhibited from the Malay peninsula, from Schlaggenwald, in Bohemia, and from Spain.

Zinc is comparatively a metal of very recent introduction, but is now daily assuming a greater importance. Thirty years ago, the uses to which this metal was applied were very limited, and it is supposed to have been unknown to the Greeks and Romans. It has, however, been long known to the Chinese, and was formerly imported in large quantities by the East India Company. It is obtained chiefly from the carbonate ot zinc or calamine; it is also obtained from the silicate and sulphuret or blende, which is known to English miners by the name of "black jack," and was thought to be valueless, until the year 1738, when a method of reducing it was discovered. This method, however, is not now carried on to any great extent.

The principal localities where zinc is found are at Tarnowitz and other districts in Upper Silesia; at Raibel in Poland, and Bleiberg in Carinthia; at Limburg, in the Netherlands; at Altenberg, near Aix-la-Chapelle; in Derbyshire, Alston Moor, the Mendip Hills, &c.; in the Altari mountains, in Russia in New Jersey, Virginia, and some other parts of the United States of America; besides some districts in China, of which very little is known to Europeans. The calamine (carbonate of zinc) and electric calamine (silicate of zinc) are prepared for reduction by breaking the ore into small fragments, separating the impurities as far as possible, and then calcining, either in a kiln or reverberatory furnace. When the latter method is employed the ore is frequently stirred about with an iron paddle, by which a fresh surface is constantly exposed to the action of the heated gases of the furnace. By this treatment the water and carbonic acid of the mineral are entirely expelled, and at the close of the operation, which usually lasts from five to six hours, the charge is raked out and allowed to cool. The prepared ore is then mixed with about one-seventh of its weight of powdered charcoal, and is reduced to the metallic state in vessels specially adapted for this purpose. In the English process these vessels are large crucibles placed under a dome, similar to those of the common glass furnace, and heated by a fire placed in the grate in the middle of the sole. These crucibles are provided with tight-fitting covers, and are pierced at the bottom with holes, in which are fitted iron tubes; these, after traversing the brickwork of the bottom of the furnace, descend into closed receivers filled with water, which are placed in niched recesses, situated at the level of the ground on which the furnace has been built.

The zinc, which is reduced by the charcoal present in the charge, now rises in vapour, and passes down the

tubes into the condensers, where it collects in drops or powder, mixed with a greater or lesser quantity of oxide. The metal is afterwards melted again, and cast into bars, and the oxide which forms on its surface is returned into the crucibles, after the addition of a due admixture of charcoal.

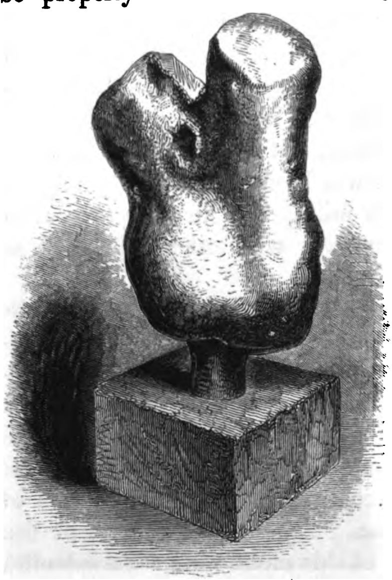
Zinc was very fully illustrated at the Great Exhibition; but principally by one company, whose products were shown in two or three different departments. This company, known as the Vielle Montagne Zinc Company, is one of the most important mining concerns in the world. It employs 2,646 persons, and produced in 1850 not less than 11,500 tons of zinc. Their reducing furnaces are 80 in number. Among the objects they exhibited were a colossal statue of the Queen, cast in zinc, and 21 feet in total height; sheet zinc, perforated zinc, zinc nails, vessels of various kinds, paints, &c. Another remarkable object connected with this metal was the huge block of zinc, a representation of which is given in a volume preceding this work. This enormous block weighed 16,400 lbs., and was obtained from the New Jersey Exploring Company's mine at Sterling Hill, in Sussex County, State of New Jersey. The ore is an oxide of zinc, and is extremely rich and pure. Millions of tons of ore are actually visible above water-level, and requiring merely to be quarried in order to be extracted. The block was got out accidentally in the ordinary course of mining, at a single blast, from near the surface on the brow of the range of hills in which the vein outcrops. The mine was opened only last spring, and with a small force nearly 3,000 tons of ore were got out and brought down to the works of New Jersey Exploring and Mining Company, which are situated on tide water, a few miles from New York. The Morris Canal furnishes ready and cheap transportation for the ore generally; but being closed by ice last season, before

it was determined to send this large sample to the Great Exhibition, unusual means had to be adopted to get it to New York, at an expense of about 200*l*. No means of moving a mass of such immense weight being at hand at the mines, a truck of the largest size was sent for the purpose from New York. The first attempt failed, from want of proper apparatus, and the truck returned. A second truck, fitted out completely for the service, was then despatched, the company having determined to send this fine sample of ore to the Exhibition at any cost. The task was one of greater difficulty than may be supposed, for within twenty miles from the mines three high ranges of mountains were to be crossed; it was mid-winter and the roads were bad, and in some places quite precipitous. Heavy teams of horses and oxen were required to draw the truck up the mountains, and, in descending, it had to be held back by means of strong block-and-tackle rigging, fastened to the trees on the road side. Being thus transported over the mountains, a distance of twenty miles, the ore reached the town of Dover, the terminus of the Morris and Essex Railway, upon which it was brought to the city of New York, a distance of forty miles. Its further progress to this country was in company with other objects from the United States.

Brass, a metal of much value and importance in manufactures, is, as is well known, a compound substance, being an alloy of copper and zinc. It is generally made by fusing together two parts of copper and one of zinc. A large quantity of this alloy is made for various purposes, and it is largely consumed in Birmingham for the production of various articles of hardware and decoration. Among the objects at the Great Exhibition made of this metal were some splendid specimens of skilful workmanship sent by MM. Estivant from France. Among them were a sheet of rolled

brass, nearly 16 feet long by 3 feet 7 inches wide, and less than a quarter of an inch in thickness. There were also two large pans of hammered brass, each 7 feet 7 inches in diameter, and 15 inches high. There appears to have been some secret adopted in the manufacture of these large articles, which are very difficult of production by other makers, very few being able to roll out the metal into large sheets without its being cracked and flawed. The manufacturers received a Council Medal from the jury of their section. Among other articles they exhibited also a roll of brass wire not more than the 1-20th ot an inch thick, and 3,691 yards long, perfectly uniform throughout, and weighing 105 lbs. 10 oz.

The series of metals called noble metals can scarcely be properly considered in a work on manufacturing industry, since from their scarcity and high value they do not directly form a part of ordinary industrial operations. A few brief notes may, however, form an appropriate termination to our present chapter on Mines and their Products. The accompanying cut represents a magnificent specimen of native gold shown at the Great Exhibition. It was obtained in



California. The discovery ot this precious metal in Australia and in California constitutes one of the most in-

teresting and remarkable facts in the history of the world. More persons have been probably influenced directly or indirectly by the finding of a few tons of this metal than were affected by the conquests of an Alexander or the dominion of a Napoleon. Hundreds of thousands of individuals have been set in movement, nations have been agitated, and every department of industry has experienced commotion, and all in consequence of the detection of some shining grains of gold in the quartz rocks of California, and in the river mud of Australia. It is unnecessary here to allude to the well-known circumstances attendant on the discovery of this metal in America and in Australia. At the Great Exhibition fine specimens of gold were shown, which were obtained in Canada; others were sent from India; from the United States gold ore and manufactured gold were exhibited. There were also samples from West Africa, and some particularly deserving of notice from Chili. It was a lump of solid gold ore, weighing 3 cwt., and was brought up on the back of a miner from a depth of 135 feet below the surface. This mass was said to contain 12 ounces of gold and 220 of silver.

One of the most interesting exhibitions of gold was a small case of specimens, obtained from Reichenstein in Silesia. The ores of this mine are arsenical pyrites, and contain about 200 grains of gold to the ton. These are roasted in a reverberatory furnace, surmounted by a large condensing chamber, in which the arsenic is deposited as it rises in fumes. Oxide of iron, a certain quantity of arsenic, and the gold in the ore, remain beneath. These are placed in a vessel, so that a current of chlorine gas is sent through them. The gold and iron attached are separated from the residue by solution in water, and the gold is precipitated by sulphuretted hydrogen. It is then washed and heated in a crucible, to drive off the sulphur, and the gold is reduced to the

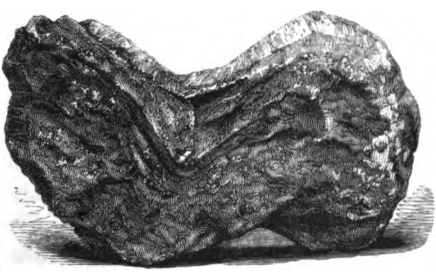
metallic state in the usual manner. By this simple and ingenious process, invented by Professor Plattner, mines which have been closed for five hundred years have been reopened, and ore containing only 200 grains of gold in a ton has been made to pay for the working. This process was rewarded with a Council Medal.

Gold may be obtained by washing the alluvial deposits and sands of the gold districts. It is also largely procured by washing the stony ores in which a few glittering grains are found. It may be obtained by amalgamation with mercury, which may be driven off in vapour, and the gold is left behind. Among other impurities associated with gold are small quantities of silver, iron, and tin. The iron and tin are separated by adding nitre to the gold in a crucible. The silver is removed by solution in an acid. In order to effect this separation completely it is necessary that the alloy should contain at least two-thirds of its weight of silver, without which it would be scarcely attacked by the acids. Sulphuric acid is employed by the gold-refiners and at the Mint for this purpose. When the alloy to be operated on does not contain the requisite amount of silver to render it easy of attack by the solvents employed, it is fused with a proper quantity of this metal previously to being treated by the acid. That part of the operation in which the alloy is again fused with an addition of silver is called quartation or inquartation—whilst the actual separation of the two metals, by means of acids, is known by the name of "parting."

When the alloy has been brought to the standard best adapted for the action of the solvent employed, it should be either laminated or granulated, and the black flocculent substance which remains at the bottom of the vessel is, after being well washed, to remove the adhering silver, either at once fused into ingots, or melted with the addition of a little lead, and after-

wards passed to the cupel, where the lead is oxidized and pure gold left behind.

Silver was more abundantly shown than gold on the occasion in question. The cut shows a splendid specimen of native silver, sent from Chili, and exhibited near the large mass of rock crystal contributed by the Duke of Devonshire, in the nave on the foreign side of the Great Exhibition. This mass weighed 154 lbs. It was obtained from the mines of Descubridora, near Chanarcillo, in Chili. The dimensions of this specimen make it interesting in natural history, and its structure was extremely singular. It was formed of successive layers folded in each other like the leaves of a book. This appearance is imperfectly shown in the engraving. The enormous cakes of silver obtained from lead have been already spoken of.

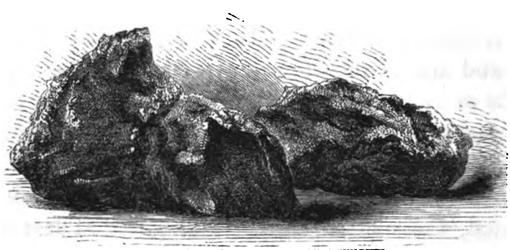


Silver ores generally consist of vitreous silver, red silver, and arseniuretted ores with silver. The ordinary methods of reducing silver ore are by smelting, and by amalgamation. The separation of silver by smelting is effected by the power of cupellation, which consists in oxidizing and burning off the impurities with which it is associated, the metallic silver being left at last nearly pure. The completion of the process being known by the metal becoming very brilliant, and on cooling throwing out arborescent sprouts resembling the branches

of some kinds of coral. Silver is also separated when in combination with lead by the process of crystallization, invented by Mr. Pattinson, and already alluded to. When amalgamation is the process employed, the silver ore is brought to a state of chloride by a mixture of the powdered ore with about ten per cent. of common salt. The chloride is then reduced by metallic iron in filings, and the silver being liberated combines with the mercury added to the mixture. The amalgam is then washed in water, and on distillation by a strong heat the mercury passes off in vapour, and is condensed in a large receiver containing water, the almost pure silver being left behind.

In addition to the specimens of this metal already noticed, were some fine specimens from Prince's Location, Lake Superior. There was also an ingot of pure silver from the smelting establishment of Stolberg, and silver ore from various parts of Electoral Hesse, also from Bavaria, and from Russia. The latter were obtained from the imperial works at Altaisk, in Siberia. These mines annually produce about 47,800 lbs. of pure silver.

Platinum is obtained chiefly from Russia, and some magnificent specimens were exhibited from that country, which are shown in the annexed cut. There were lumps



of native platinum, exhibited by Messrs. Demidoff, and weighing nearly 70 lbs. avoirdupois. Such specimens

were probably never seen in this country before. In addition to these some fine specimens of native and manufactured platinum were exhibited by Messrs. Johnson, of Hatton-garden, and a large still of this metal was shown by a French exhibitor. For many years after its discovery, platinum was, on account of the difficulty of obtaining it in masses, an almost useless metal. When strongly heated, the grains are readily welded together, but, from the smallness of the fragments, this causes interminable labour, and besides does not afford a pure metal. The process now generally adopted was first introduced by Dr. Wollaston, and consists in dissolving the native metal in hydrochloric acid, and then throwing down from the solution an orange-coloured precipitate by means of muriate of ammonia. This precipitate, which is a double chloride of platinum and ammonium, is then heated and reduced to the metallic state; the platinum is then in an extremely minute state of division. This black powder, which is spongy platinum, is next compressed in steel moulds by the aid of heat and strong pressure, and, when sufficiently compact, is forged under a hammer, by which it is ultimately reduced to a solid mass.

With the mention of this metal we shall conclude our Chapter on Mines and their Products. Since those substances which have been discussed in this part of our work form the basis of all successful prosecution of industrial art, the propriety of fully entering into a consideration of them will be manifest: for all that we have got to speak of, concerning the triumphs of man and the powers of mechanism, could never have had an existence but for the metals.

CHAPTER II.

SOURCES OF MECHANICAL POWER.

It is not easy in our own age, when every person is familiar, from the earliest period of childhood, with the existence of the steam-engine, and other prime movers, to realize a time when man was without any such addition to his resources,—when he was dependent solely on his own physical power, or upon that of the beasts of burden, and was ignorant of the latent force of water, air, and fire. Yet such a period in the history of our race is not very far remote, and many savage tribes are still in the same condition, often ignorant of the simple powers conferred by the pulley, the wedge, and the screw, and still more frequently of any form of engine by which force can be generated, directed, and applied to the purposes of industry. With what feelings of pleasure and surprise must that man have looked upon his work, who first got the running waters or the breathing winds to do his bidding, and to bear the burden of his daily toil, to pump the water for his fields, or grind the corn for his food! And it is a matter of very recent history with what intense satisfaction those men looked upon the results of their labour who first subjected steam to human control, and saw the iron and the brass become instinct with motion, and endowed with active power. That was a proud moment when a man like Watt beheld his first engine rise in obedience to the power which he forced into its iron

frame, and move and toil with an untiring strength at his direction and command.

The subject of our present chapter is one of great interest and of large extent;—but it requires limitation, and we shall therefore simply give an account of the present condition of mechanical sources of power, without entering into the history and progressive advancement of our resources in this respect. Since this work proceeds chiefly upon the assumption that the Great Exhibition of 1851 constituted, in all essential particulars, a type of the present condition of industry and its results, it will be evident that our business chiefly lies with what was there shown. And truly, that wonderful collection of the triumphs of human skill was well furnished with specimens of those astonishing pieces of mechanism by which a more than gigantic power to work, to forge, and spin, and weave, to fly, and lift, and dig, is obtained by man. These are called Prime Movers, and to these, in all their most important varieties, we shall now address our attention.

A Prime Mover is to the manufacturer of the very first consequence. It constitutes his Great Operative, without whose powerful aid all the human hands employed would be able only to accomplish small and feeble results. The ponderous machinery of the factories were all a useless erection unless it could be put into full and continuous movement, and for this purpose the Prime Mover is necessary. All the rest of the machinery is only secondary in its importance compared with that which gives, so to speak, life and activity to the whole. The following descriptions of machines constitute the class of Prime Movers:—steam-engines, wind-mills, water-wheels, air-engines, electro-magnetic engines, vapour-engines, &c. These may be described in a few words as combinations of mechanism adapted to communicate motion. Some

of these generate the force which actuates them, as the steam-engine, electro-magnetic engine, &c. Others are merely arrangements for collecting mechanical power, either from the natural movement of water—as in water-mills, tide-mills, &c., or from that of the air—as in wind-mills. Engines belonging to the latter class are dependent upon a supply of force, by its very nature uncertain and often intermittent, and which, if deficient, cannot be increased by man. Whereas the steam-engine and its allied machines is absolutely at man's disposal, can be forced up to any amount of activity, can be set in action at any required time, and can be arrested at a moment's notice. The steam-engine, consequently, as the slave of man, is the machine which is most highly valued, and which, under skilful direction, has accomplished more than any other machine for the promotion of the comfort, convenience, and well-being of mankind.

Essentially, the steam-engine consists of the following parts:—1, The expansive vapour; 2, The cylinder and piston, with its attachments; and 3, The crank, shaft, and fly wheel. The vapour generated (from the application of fire to water, contained in an iron receptacle called the boiler,) is forcibly retained there, in consequence of the perfect closure of all the seams and joints, and also of its exit-pipes, by means of stop-cocks, until the elastic force which it acquires under these circumstances reaches the point necessary for the purposes of the engineer, or, in other words, until it is strong enough to lift up the piston against the weight of itself, the rod, connectors, &c., and the resistance of the crank and shafting and load.

On leaving the boiler, the steam, in a highly elastic state, is directed through a large pipe to the cylinder. This is a hollow trunk made of iron, closed at the top and bottom, and in the polished interior of which a piston moves up and down, the rod passing through a

hole in the tight fitting cover of the cylinder, just like the common piston of a syringe. In order to cause the steam to press alternately on the upper and on the lower surface of the piston,—which is packed so as to move easily, but yet to be steam-tight as it passes up and down the cylinder,—openings are provided at the top and at the bottom. Let us now follow the steam in its action on the piston:—A valve opens which communicates with the pipe charged with steam, and instantly it rushes through the opening which leads to the bottom of the cylinder. There it is stopped in its progress by the piston, and, in order to get further, it must push up the piston, and in so doing it necessarily thrusts up the rod which pushes on the crank, and begins to turn the shaft. When the steam has pushed the piston up as far as it will go, another valve opens below, and lets all the steam in the cylinder escape. But, at the same moment, a third valve opens at the top, and pours down upon the top of the piston a powerful volume of steam. Under the pressure of this the piston descends, dragging the rod, crank, &c., after it, and goes on descending until it reaches the bottom. On reaching this point a fourth valve opens at the top, letting out all the steam of the cylinder in that way, while the first valve is at the same time thrown open at the bottom, and a fresh charge of steam is thrown into the cylinder, which pushes up the piston,—and so on alternately, so long as steam is supplied to the machine

Out of the many thousands who are familiar with the appearance of the steam-engine in this country, there are probably hundreds of persons who have not a clear and satisfactory idea as to the manner in which the steam does its work, and sets the machine in motion. Yet, the above short and simple account contains all that is really essential to be known in order to understand fully the manner in which the locomotive flies

across the country, and in which many stationary high-pressure engines fulfil their task. The principle is simply this:—The expansive force of steam presses alternately below and above the surface of the piston. In so doing it thrusts it up and down. In order to convert this up-and-down movement into one of revolution, so as to drive wheels and shafts, the contrivance called the crank is used; and this is identical with the same contrivance as it is applied to the turning of a lathe, or by the knife-grinder in the street, in order to set his wheels in motion.

Such is the principle of the high-pressure steam-engine in its direct and simplest form. If pains are taken to get a clear comprehension of this principle, all other varieties of the steam-engine will be easily understood.

The low-pressure steam-engine takes advantage of another property of steam in addition to its expansive force. This is its property of becoming instantly condensed to water when exposed to cold, and consequently the production of a vacuum in the space formerly occupied by the steam is the result. If a flask were charged with steam to the utmost limit of its power of resistance, and were suddenly plunged into cold water, all the expansive force of the steam within would be annihilated almost in a moment, and only a few drops of water would be found at the bottom of the flask. This property is applied to the steam-engine in the following manner:—Let it be supposed that the steam, after having been admitted underneath the piston, has expanded and driven up the piston, and is waiting to be dismissed from the cylinder after the completion of its task. Instead of allowing it to escape into the open air, as in the high-pressure engine, a valve is opened which conducts it into an iron chest surrounded by cold water; here it instantly becomes condensed, and thus produces a vacuum under the piston, which is now

descending under the full pressure of the steam let on above it. The piston of course descends much more rapidly under such circumstances than if it had to push the spent steam before it into the open air; for it is now sucked down as well as pushed down by the steam above. When its descent is complete, the steam above it is conducted into the same vacuum-chamber, and is condensed, while steam is again let on beneath; and thus the piston is now sucked upwards by the vacuum above it, and pushed up by the steam below. This familiar explanation is not intended to give a strictly scientific view of the operation of the low-pressure engine; but it conveys a sufficiently accurate view of it for all ordinary purposes.

The point now reached in our view of the steam-engine is this: That a perpendicular up-and-down movement is obtained by the alternate pressure and removal of steam admitted into, and withdrawn from, an iron cylinder containing a piston, which moves steam-tight within it. Such is the elementary idea embodied in both the high-pressure (or non-condensing) and the low-pressure (or condensing) engine. We shall now proceed to show how this motion can be propagated, directed, and converted for the ordinary purposes of the manufacturers. For this object there are several parts of the steam-engine to which attention requires to be drawn.

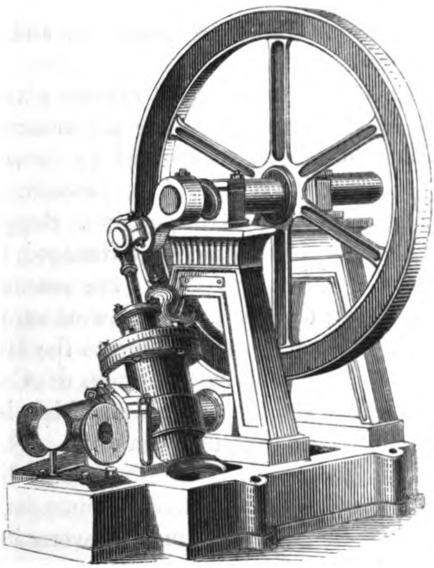
If no other motion could be obtained from the steam-engine than a rectilinear or perpendicular one—which is the first direction of force in this machine, expressed by the rise and fall of the piston and its rod,—it would have been but of comparatively little value to the manufacturer, or for most of the purposes for which active power is required. For pumping up water or air such a movement is all that is requisite. But every sort of manufacturing machine requires a movement of rotation in

order to actuate it, and, by a simple and ingenious adaptation, this has been obtained from the steam-engine. The handle of a barrel-organ, or that of a windlass for drawing up water from a well, furnishes a simple illustration of that part of the steam-engine called the crank. If we suppose the piston-rod of a steam-engine connected directly with a bent lever, such as that of the barrel-organ, it is obvious that it could not move it; for the rod can only move up and down in a straight line, and not laterally. But if a jointed piece were fitted on the end of the piston-rod, which permitted of lateral motion, and the other end of this piece were connected with the handle, then the piston-rod could move up and down, and the jointed piece would adapt itself to the swaying movement of the handle, and, at the same time, convey to it the pressure of the piston. In this way a movement of rotation would be obtained out of the rectilinear motion of the piston. Let the piece of wood on which the knife-grinder treads represent the up-and-down movement of the piston, then the bent hook attached to this wood below and to the crank above, will represent the jointed piece in question, and the crank will receive through it a rotatory motion, from a force in the first instance acting perpendicularly.

The crank thus fulfils the office of a connecting medium. It receives a rectilinear force, and in yielding to it sets up a movement of revolution, through the shaft or iron rod to which the crank itself is attached, and of which it forms a part. The fly-wheel is placed on this shaft, and by its momentum serves to equalize and propagate the motion of the machine. From this shaft movement is communicated in any required direction, by means of straps and pulleys, or by cog wheels, couplings, &c.

In many forms of the steam-engine the whole of the

essential parts of the machine consist merely of the cylinder and piston and the crank; the piston rod being directly attached to the crank, and the oscillating or swaying movement necessary in order to give it free action, being obtained by causing the cylinder to sway from side to side. (See Cut.) These constitute the simplest examples of a direct rotatory movement being obtained from the combination of the piston-rod and



crank. Very generally, however, an intermediate mechanism is necessary. This is called the beam. It is, as its name implies, a ponderous beam of iron, resembling that of a pair of scales, and supported like that on a central axis, which permits of its rising and falling alternately. To the one end of the beam the piston-rod is connected by a jointed piece, and to the other the crank-rod, a perpendicular bar of iron, jointed at the top to the beam and at the bottom to the crank. In order to

keep the piston rod precisely straight in its rise and fall, an elegant arrangement of pieces of metal is attached which counteracts the tendency of the beam to push it to one side or to the other. This arrangement is called the parallel motion. The beam, actuated by the rise and fall of the piston rod, communicates this motion to its opposite end, where the crank rod is fixed in a pivot, and thus the crank receives its motion through the medium of the beam. To the sides of the beam are attached various rods which serve for pumping, and bringing movement to the valves.

Having thus in a very succinct manner given an outline of the essential points in the construction of this beautiful machine, we shall proceed to show in what way, after being once put in motion, it sustains its movements and becomes a self-acting engine. Supposing the mechanism to be complete and well arranged, in a state, in fact, fit for working, two things are essential to its continued activity; these are, a continuous supply of fire and of water. We are now alluding to the High Pressure Engine. In the Low Pressure, or Condensing Engine, one thing further is requisite, which is the due exhaustion of its condensing chamber. The steam-engine can be and often is so admirably adjusted, as perfectly to attend to itself, to feed its furnaces, to replenish its boilers, and, in addition, to govern its rate of movement. By an arrangement of hoppers and an endless chain of bars the furnaces may be fed with fuel, simply by communicating motion to this mechanism from the shaft, and in this manner a continuous supply of coal is placed on the fire, leaving the stoker little to do beyond raking out the slags and refuse from between the bars. Water is supplied to the boiler in a manner equally simple and ingenious. By a glass guage communicating with the boiler, the engineer can always determine its amount in a high-pressure boiler, and he

has merely to feed the pump moved by the engine with more or less water, to render the supply equal to the loss by evaporation. In a low pressure boiler this also is in a great measure automatic, and the rise or fall of a float inside the boiler admits less or more water to it as may be necessary. The feed-pump for supplying water to the boiler is in a beam engine attached to the beam itself. In other forms of engines it is moved by the shaft by an ingenious contrivance for converting rotatory into rectilinear motion back again, called an Eccentric. This consists of a circular piece of iron through which the shaft perforates and is attached, but not at its centre, but nearer its circumference. In consequence of this arrangement, as the shaft revolves it carries the largest portion of this circle alternately to and from any point, and by surrounding its rim with a loose iron band, to which a rod is attached, a thrust to and fro is obtained, or, in other words, a rectilinear action is communicable, which is transmitted to the rod of a force pump. Thus it will be seen that the steam-engine can be made to supply itself with fuel and water, and so long as these are placed within its reach the machine will go on, and require but little attention on the part of man.

In the Condensing or Low Pressure Engine it is found that the chamber where the steam is condensed, after it has done its work in the machine, requires to have its vacuous condition sustained in as perfect a state as possible by an exhausting pump, in consequence of the entrance of a little air together with the steam, which, with the condensed water, would in time accumulate and destroy the vacuum formed by the condensation of the steam. This pump consequently removes both any portion of air which may happen to be present and also the water formed by the condensation of the steam. In order more completely to condense the steam

a small cock opens inside the vacuum chest and throws in a fine jet of cold water. This is also removed with the rest by the exhausting or air pump.

The fly-wheel, which we dismissed with a few words of notice, a little way back, deserves attention here. The steam-engine, as far as we have now considered it, is complete,—it can move and act; but, if set in motion, its movements would be capricious and intermitting but for the intervention of the fly-wheel. The object of this large and ponderous wheel is to equalize the motion of the machine. This it does by virtue of its inertia, and also of the momentum it acquires when in motion. If the moving power slackens, the momentum of the fly-wheel carries the machinery on; if it tends to impel the machine too fast, the inertia of the wheel resists it and slackens it. The fly-wheel thus serves to absorb a redundancy of power, and also to give out power when it is deficient. It has been aptly compared to a reservoir which collects intermitting currents of water, and gives it out in a regular stream. Let us suppose, for example, that the steam-engine is toiling to keep in movement a vast room filled with self-acting looms. This probably taxes its power severely, and the boiler and furnaces are kept to a high state of activity to meet the demand. Suddenly the whole range of machines is disconnected, their work being done. The enormous burden is instantly thrown off the engine, and it has a tendency now to fly at a furious rate. The fly-wheel, however, preserves the machine from destruction, by the inertia of its ponderous mass which refuses to fly off at the first impulse. In this way a balance of power is preserved.

The fly-wheel, however, is efficient only up to a certain degree; for if, in the case just supposed, the full pressure of the steam were allowed to go on, it would ultimately overcome, in a few minutes possibly, the inertia of the

wheel, and this immense piece of mechanism would be the first to fly to pieces with the enormous velocity acquired. This emergency the sagacious James Watt foresaw, and made a beautiful and admirable provision against its occurrence. It occurred to him that the velocity of the fly-wheel might be regulated by diminishing or increasing the supply of steam to the cylinder. If the wheel were revolving too fast, less steam might be admitted; if too slow, more might be turned on. In order to effect this and to render it independent of the engineer, Watt contrived the Governor. This part of the steam-engine consists of two heavy balls of iron attached to two bars which are placed on a perpendicular shaft set in motion by the main shafting. When these balls revolve very rapidly, they have, as will be easily understood, a powerful tendency to fly apart by centrifugal force. When they turn slowly, they fall in and lie close to the shaft. By fitting to the bars supporting these balls a movable socket which was so adjusted as to fall when the balls flew wide apart, and to rise when they fell close together, it was possible to adjust a lever to this mechanism, the further end of which was connected with a valve in the steam-pipe, and moved it so as to open or shut according to the rise and fall of the socket in question. The action of the governor is therefore very simple. The fly-wheel is revolving at too high a speed, the balls begin to separate and soon fly wide apart; in so doing they forcibly pull the socket in question, which in turn presses down the lever, and this closes the valve, and so cuts off the supply of steam. The velocity of the engine now diminishes, more steam is wanted, the balls fall in, thrust the socket up, which pushes up the lever, and this throws open the valve (appropriately called a throttle-valve), and once more a full supply of steam is received by the cylinder. In actual practice this principle of regulating the speed

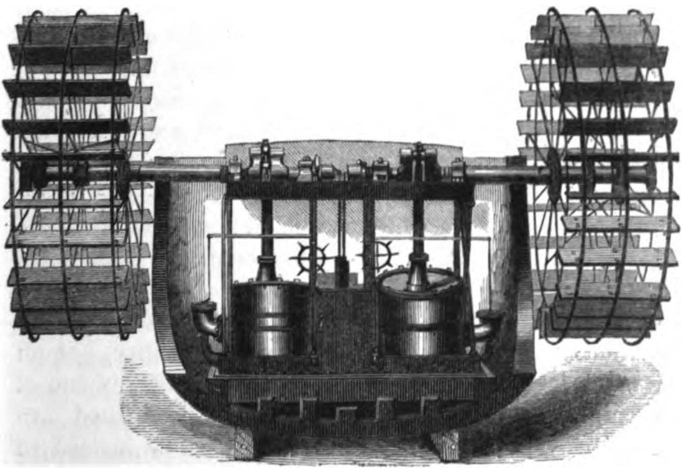
answers perfectly well, and a continuous rate of motion is obtained, neither too slow nor too fast, for the governor does not act intermittingly but constantly, and in so doing preserves uniformity of movement in the powerful machine which it controls.

The reader is now in a position to form an accurate and comprehensive view of the general principles, both of the non-condensing and of condensing steam-engines. We have endeavoured in the simplest manner to show how steam generated under pressure, may be made to do work for man, and become his most useful and unwearied servant. We shall now select a specimen of each of the best kinds of engines, making our choice out of the admirable display sent to the Great Exhibition.

A better specimen of a condensing engine could scarcely have been pointed out, than the magnificent one sent by the modern representatives of the once splendid establishment of Boulton & Watt. This venerable firm is still in existence, and is largely occupied in the production of the best class of steam-engines. These engines are thus described in the catalogue:—

These marine engines, of the collective power of 700 horses, with four cylinders, are designed for driving the screw propeller by direct action at 65 revolutions per minute. The object of the inventor has been to combine lightness and compactness relatively to the power, with simplicity of arrangement. These engines can be placed in the ship entirely below the water-line, whereby they are protected from the effects of shot in vessels of war; and in the mercantile marine the decks are left clear for passengers or cargo. These engines consist of four horizontal cylinders—the cylinders each of 52 inches diameter and 3 feet stroke, 65 strokes per minute; the screw itself is 16 feet diameter, and makes the same number of revolutions. The cylinders are coupled in pairs direct on to one shaft, which is cranked in the

middle, to work the two air-pumps, which are fixed in an inclined position between the steam cylinders and below the platform, where the starting gear is worked. The condensers are also between the cylinders. The bilge and feed pumps are worked from a light crank shaft at the forward end of the engines, and are very easy of access. The air pump valves are of vulcanized Indian rubber. The link motion is applied to work the slide valves, and the whole arrangement is simple and compact.



These engines were valued at £16,000, and were certainly of beautiful workmanship and skilful combination of parts; they were doubly interesting from the fact, that at one period, James Watt doubted the applicability of steam for ocean navigation. His successors have given a singular contradiction to his opinions, and his own manufactory contributed to the Great Exhibition of 1851, the most splendid set of engines it contained, for the sole function was ocean navigation. The error of James Watt may teach us humility for

ourselves in estimating the probable future of the advancements of science.

In these engines the cylinders were fixed; but a large number of condensing marine engines are now built, which from their swaying motion from side to side are called oscillating cylinder engines. The cylinders in these engines are placed on a movable axis at the bottom, and the piston rod is directly connected with the crank. Some very beautiful engines of full size on this principle, were exhibited by Messrs. Penn, who have long enjoyed celebrity for this class of steam-engines. They were a pair of 16-horse engines with oscillating cylinders. They were of their usual size and pattern, as fitted into the numerous river boats on the Thames, and were a most excellent sample of workmanship and proportion. The cut shows the relative position of the engines and the paddles. They were fitted with two different paddle-wheels, to show the variety—one being that of the common wheel with fixed floats, and the other a wheel with "feathering" paddles, similar to those made where great speed is required. Some of the very fastest of the steam vessels on both the Dover and Holyhead stations are also fitted with this sort of engine, but on a much larger scale. The celebrated *Banshee* is one of them. Engines on this plan have also been fitted into the Queen's yacht *Fairy*, but with a screw instead of paddle-wheels.

The Great Exhibition also furnished an opportunity for the illustration of another kind of marine engine, called the trunk engine; and one of these ingenious constructions was in actual work. There was also a pair of 30-horse engines for the screw propeller: they were horizontal trunk engines with fixed cylinders. In these engines simplicity of arrangement is studied and carried out to a very remarkable extent. The connecting rods are attached to the centre of the pistons,

which, instead of being solid, are hollow iron tubes, within which, the rod to the crank is attached, at one end, and to the crank shaft at the other. They are intended to run 115 revolutions per minute. The air-pumps are fixed in the condenser, and are worked direct from the pistons, each by a horizontal rod working through stuffing boxes in the cylinder cover and the pump cover: they are, of course, horizontal, and are double acting, so that their dimensions are reduced to a minimum consistent with their effective action. Their valves are made of vulcanised Indian rubber, and although worked at great speed, are quite noiseless. The feed-pumps are worked in a similar manner, but are single acting only, as this is more convenient. All the parts are easily got at, and the starting and reversing gear is very conveniently placed. Engines on this plan, but of much larger size, viz. 360-horse, have been fitted to her Majesty's steam frigates *Arrogant* and *Encounter*, and their performances have been in the highest degree satisfactory. Altogether, they may be considered as great a simplification of parts compared with the previous simple oscillating engine now extensively used by all engineers, as the oscillating engine itself is allowed to be simpler than the old beam engine, which was universally used in steam vessels until a few years since, and which is not yet abandoned in some few instances.

It has, however, been objected to these engines, that the continual exposure of the part called the trunk, or hollow piston, necessarily involves a considerable loss of heat from its alternately being plunged into the cooler atmosphere from the heated interior of the cylinder. To how great an extent, however, this objection is valid, must be left to experience for decision. The engines hitherto appear to have answered extremely well, and have the advantage of great simplicity of construction and economy of room.

Another very elegant and efficient form of marine-engine, shown at the Great Exhibition, was exhibited by Messrs. Maudslay, an engineering firm of the highest eminence. The kind in question is the combination of four-cylinder engines patented by them, and generally made for large vessels. Many of them have been made, and worked for years with the greatest success; amongst other vessels, in the Queen's yacht, the *Victoria and Albert.* In these engines the three cylinders are fixed upright, and on the tops of the piston-rods are placed wrought-iron "T" pieces, which rise and fall with the motion of the pistons; and to the lower end of each "T" piece is coupled the bottom end of the connecting-rod, the top being attached to the crank. This arrangement allows of a much larger connecting-rod being used than is usually possible with direct acting engines; and also, in the case of very large engines, it reduces their separate parts to manageable weights and sizes, while the total room occupied is much less than that required by beam-engines. The air-pumps are worked by a separate pair of levers, and these latter also serve for the feed and bilge pumps. Very little framing is required for these engines, except the headstock which carries the paddle shafts.

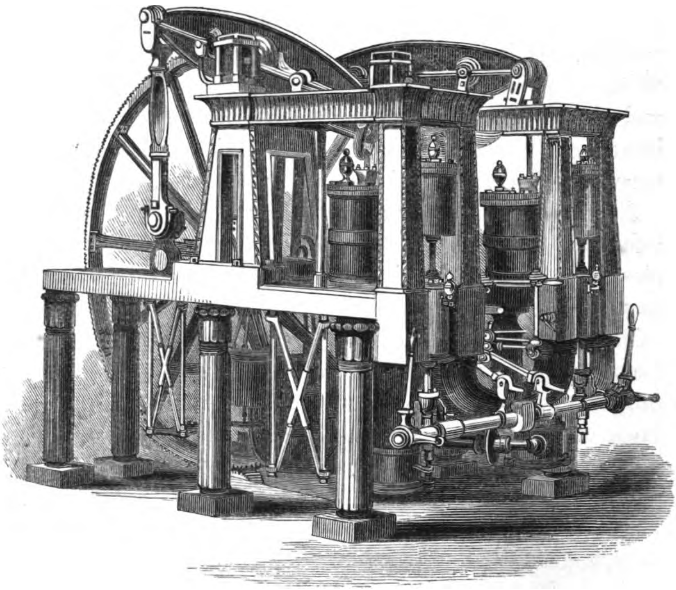
The "annular" cylinder engines, patented by Mr. Joseph Maudslay, were also represented. This description of engine has been fitted into several of the vessels trading between Folkestone and Boulogne, as well as in other vessels. They are somewhat similar in appearance to the trunk-engines before described, but with this difference—that the internal cylinder is a fixture, and two piston-rods are necessary to connect the piston to the "T" piece, whereas in the trunk-engines there is no piston-rod. The lower end of this "T" piece moves up and down in guides placed in the hollow of the internal cylinder, which has no cover

The connecting rod is attached to it and the crank, as in the double cylinder engine. The annular cylinder engine is a very clever invention; and to any unacquainted with the simplicity of its real construction, it appears to be a very unintelligible piece of mechanism, and is, in many respects, very different to the ordinary form of steam-engine. Essentially, however, it is the same; the principal difference being that the piston, instead of being a circular mass, is a hollow broad ring, with a piston rod on each side of the central hollow portion. It is objected to this engine, that the friction of the ring-like piston against the sides of the outer, and also against those of the inner cylinder, is likely to interfere with its efficiency. This engine effects a great economy of space, and is simple in its parts.

Specimens of the marine beam-engines were also exhibited by different engineering firms; but as this class of steam-engine is now going quite out of use for marine purposes, it is not necessary to make further allusion to it in its modifications for that purpose. Some magnificent models of large beam-engines for land purposes were shown. One of these, sent from Messrs. Hick of Bolton, in Lancashire, was extremely beautiful. It represented a pair of condensing engines of vast power, erected by them for a cotton-mill in that county. These engines are a wonderful specimen of engineering skill, and are fitted with a governor of simple but peculiar design. They are shown in the cut.

In many of the engines exhibited the principle of working the steam by expansion, or in shorter terms, the expansion principle was shown. This principle deserves to be understood by the reader, since it constitutes a great improvement over the original method of supplying steam to the cylinder. It is thus explained by Professor Moseley: "The advantages to be obtained by working steam expansively, long known to men of

science, are now generally acknowledged. It is indeed obvious, that by admitting the steam to the cylinder at *a higher pressure than that of the load*, and cutting it off before the stroke is completed, the piston, and the mass it carries with it, are driven in with a continually increasing velocity, until by the expansion of the steam, after closing of the valve by which it is admitted, its pressure is reduced to an equality with the load; when



the piston does not stop, by reason of the momentum it has acquired, but is carried on, the steam yet further expanding, until the whole is at length completed, and a cylinder-full of steam is discharged expanded considerably *below the pressure* of the load. Whereas by working without expansion, at what is called full pressure, a cylinder full of steam is expanded at every stroke, of *the full pressure* of the load." Engines are

now largely constructed on this important principle, and the desired result (of cutting off the steam at half stroke) is effected by what is called expansion gear.

Before quitting the subject of marine and condensing engines generally, the following facts upon the present condition of our ocean steam navigation deserve attention. The statement appeared originally, upon competent authority, in a report contained in the *Times* newspaper. About 1836-7, the project of crossing the Atlantic was first started. The *Sirius* was, we believe, the first steam-vessel which performed it; the *Great Western* soon followed; then came the ill-fated *President*, the *British Queen*, and other vessels. It was found, however, that in order to render this commercially profitable, and even practicable, it was necessary to receive some assistance from government. A Canadian of the name of Cunard first obtained a grant from the British Government for a line of Post Office steamers between Liverpool and Boston.

An annual subsidy of 60,000*l.* was granted to Mr. Cunard, upon which condition the enterprise was commenced. It soon, however, became evident that this grant was insufficient, and it was raised to 100,000*l.* per annum. Further experience proving the necessity of increasing the number of voyages, and the consequent expense, the subvention was finally raised to its present amount, that is, to 145,000*l.* sterling per annum. This line of steamers is now worked regularly through the year. During the four winter months, from December to March, there are two departures per month from each side, and during the eight other months there is a departure weekly, making about 44 departures from each side per annum. These voyages make a total distance sailed of 272,000 geographical miles within the year; the subsidy, therefore, granted by the government to support this enterprise, amounts to 10*s.* 8*d.* per mile sailed.

The present force (1851) of the fleet of steamers by which this service is maintained is as follows :—

There are 4 vessels of 800-horse power, and 5 of 500-horse power, making a total of 5,700-horse power ; there are 2 steamers of 800-horse power each on the stocks which will soon be in operation, and which will make a total force of 11 vessels, having the aggregate of 7,300-horse power.

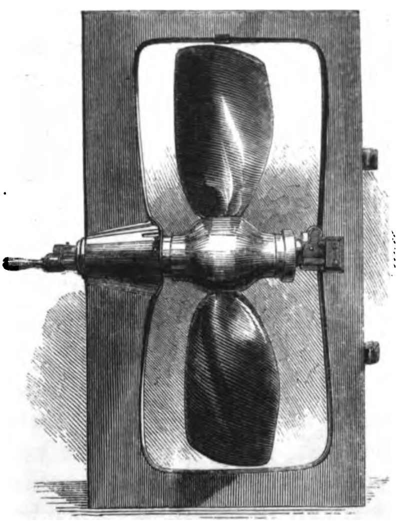
Soon after the Cunard line of steamers commenced operations, the present West India Steam Packet Company was established to form a line of steam communication between the United Kingdom and the West India colonies. An annual grant has been given to this company of 240,000*l.* In fine, all the commercial enterprises for the establishment of lines of steamers, where the voyages are of considerable length, have been supported by government, as appears by the following summary of the grants given to these companies severally :—

	£
The Cunard Company	145,000
West India Company	240,000
Pacific Company	40,000
Cape Screw Steam-packet Ship Company . .	30,000
Peninsular and Oriental Company	219,835
East India Company, for the line between Suez and Bombay	50,000
	£724,835

Thus fostered by government support, the art of steam navigation has made great progress, and within the last ten years especially the marine engine has undergone several most important modifications.

It may be known to the majority of persons that for all purposes of steam navigation only paddle-wheels were formerly employed for the propulsion of ships. Of late, however, an attempt was made by an ingenious person to substitute for it a spiral screw, placed at the stern of the vessel, and altogether out of sight. This attempt has proved remarkably successful. At the Great Exhi-

bition the inventor of screw propulsion, Mr. F. B. Smith, showed the original models he had made. Among other models of screws shown by this gentleman, were those of the actual propeller used by Mr. Smith in his experimental boat of six-horse power, in 1836-7, on the Paddington Canal, and with which she performed the first trip ever made with a screw propeller. Also the original screw, two inches diameter, made by Mr. Smith, and applied to his model working boat in 1835. While experimenting with this screw, a portion of the thread was broken off by accident, and this led to the remarkable discovery that a portion only of the screw drove the vessel faster through the water than the entire screw. This led him ultimately to adopt a screw of two blades, each blade having only one-sixth of a thread, and this apparently small instrument is found sufficient to propel the vessel with power and velocity. A more recent illustration of this fact took place in the voyage of a large screw steamer. One of the blades of the screw having been broken off by accident, the other alone not merely propelled the vessel, but apparently with an increase of speed and a smaller consumption of fuel! Sir Thomas Mitchell has very lately constructed a steam vessel having a propeller formed on the principle of the Boomerang. This vessel has been found to answer well. There is in fact

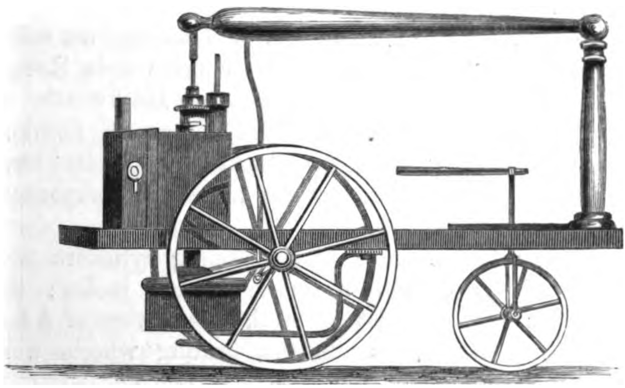


every probability of a great revolution in the propulsion of steam vessels; and it only remains to determine the best form of engine and screw for that purpose. The screw principle has the advantage of great simplicity of construction and arrangement of the engines, of economy of room, of protection from the weather, and from injury by shot in time of war; and in addition to these advantages the screw may be made to feather—that is, to oppose no obstacle to the ship's progress, so that sails may be used when the auxiliary steam power is disabled or unnecessary. The cut shows a model of a feathering screw, patented by Messrs. Maudslay. Some of our most splendid ships of war, and those whose rapidity of evolution commanded the highest admiration, have been recently fitted with screws.

It will form an appropriate conclusion to this subject, and a good introduction to the next, to mention in this place two most interesting models which were shown at the Great Exhibition, and which may be regarded as the nucleus of the application of the oscillating cylinder

to marine propulsion, and of the stationary one to locomotion on land. These models came from the works of Boulton and Watt, at Birmingham. The first of these was a wooden model of an oscillating engine. It was made by Mr. William Murdoch in 1784, in order to illustrate James Watt's patent for making the cylinder work on its axis. It is a clumsy piece of mecha-

nism, but is of value as an illustration of the infancy of this form of machine. The cut is an accurate representation of this model. The other is a locomotive carriage. The boiler is placed at one end, with a tin lamp underneath it, and the cylinder stands vertically by the side of the boiler. The motion rod is connected with a lever, to which the cramp rod is attached, and which drives the two hind wheels: a guide wheel is placed in front. A carriage similar to this was actually tried on the common road in Cornwall in 1785 and 1786. This model is shown in the cut.



We shall now take the engines applied to locomotives as the types of the high pressure steam engine in its most beautiful form and adaptation. And it is impossible to investigate this subject without feeling how very recent is all the great circle of discovery which has produced as its result our present system of railway locomotion. Long after the extended use of the steam engine by the miner, the manufacturer, and the navigator, it was still to be applied to the purposes of locomotion on land. One by one the apparent difficulties of this application disappeared, and the railroad system of this country may now be proudly considered as one of the most

wonderful of the mighty changes produced by the steam engine. The first three locomotive engines and their experimental trip have been described in the following extract from a journal published at the period of the Great Exhibition:—*

"The Directors of the Liverpool and Manchester Railway, desirous of obtaining a higher speed than was the case on the common railways for coal, &c., issued an invitation to mechanical engineers to compete for a premium to be awarded to the builder or inventor of the best locomotive engine suitable for their railway. They were satisfied, in the first instance, with a speed equal to that of the fast coaches, then running ten miles an hour. The competitors for the prize were Robert Stephenson, of Newcastle; Timothy Hackworth, of Shildon; and Braithwaite and Ericsson, of London. The 'Rocket,' the 'Sanspareil,' and the 'Novelty' were the three engines sent by the respective competitors to the great trial railway.

"The 'Rocket' had outside sloping cylinders of 8 inches diameter, with a stroke of 16½ inches: the driving wheels, placed towards the front, were of 4 feet 8½ inches diameter, while the trailing wheels were 3 feet in diameter: the boiler, at the suggestion of Mr. Booth, the treasurer of the Liverpool and Manchester Railway Company, was multitubular, and is said to have been the first of the kind used in this country; the tubes were each of 3 inches diameter, and altogether 25 in number: the heating surface of tubes was equal to 117·75 superficial feet, and the fire-box surface to 20 feet; the area of the fire-grate was equal to 6 feet; the chimney was placed in front of the engine, as in all modern locomotives; the exhaust steam was discharged into the chimney, the beneficial effects of which were soon discovered.

* Illustrated London News, August, 1851.

"The 'Sanspareil' was mounted on four coupled wheels, of 4 feet 6 inches diameter, the driving-wheels in connexion with the piston-rod being towards the back part of the engine: the cylinders were vertical, and of 7 inches diameter, with a stroke of 18 inches: the grate and chimney were situate in front of the boiler, connected by a flue tube having one bend, the diameter of the tube being 2 feet at the grate and 1 foot 3 inches at the chimney. The surface of the grate was equal to 10 superficial feet; the steam was discharged into the chimney by means of a blast-pipe, whereby the draft was materially increased. The tube surface was equal to 74·6 feet, and that of the fire-box 15·7 superficial feet. The weight of this engine was about $4\frac{3}{4}$ tons, while that of the 'Rocket' was only $4\frac{1}{4}$ tons.

"The 'Novelty' presented, upon the whole, the least cumbersome appearance, and its construction differed essentially from that of each of its competitors. The fire-box was circular, of 18 inches diameter, and surrounded by the water of the boiler; it was supplied with fuel by means of a hopper. A single tube, of 36 feet in length, with two bends, passed from end to end of the boiler three times; bellows placed near the chimney served to keep the fire alive. The 'Novelty' had only one cylinder, of 6 inches diameter, with a stroke of 12 inches; the wheels, four in number, were each of 4 feet 6 inches diameter, the driving-wheels being connected with the piston by means of bell-cranks. The heating surface of tube was only 33 feet, and a fire-box $9\frac{1}{2}$ feet, the surface of grate being equal to 1·8 foot. The weight of this engine was not much more than three tons, and during the experimental trip there was no tender attached to it. The average speed of the 'Rocket,' drawing a gross load of 17 tons, was upwards of 13 miles an hour; and the 'Sanspareil,' with a gross load of rather more than 19 tons, 14 miles

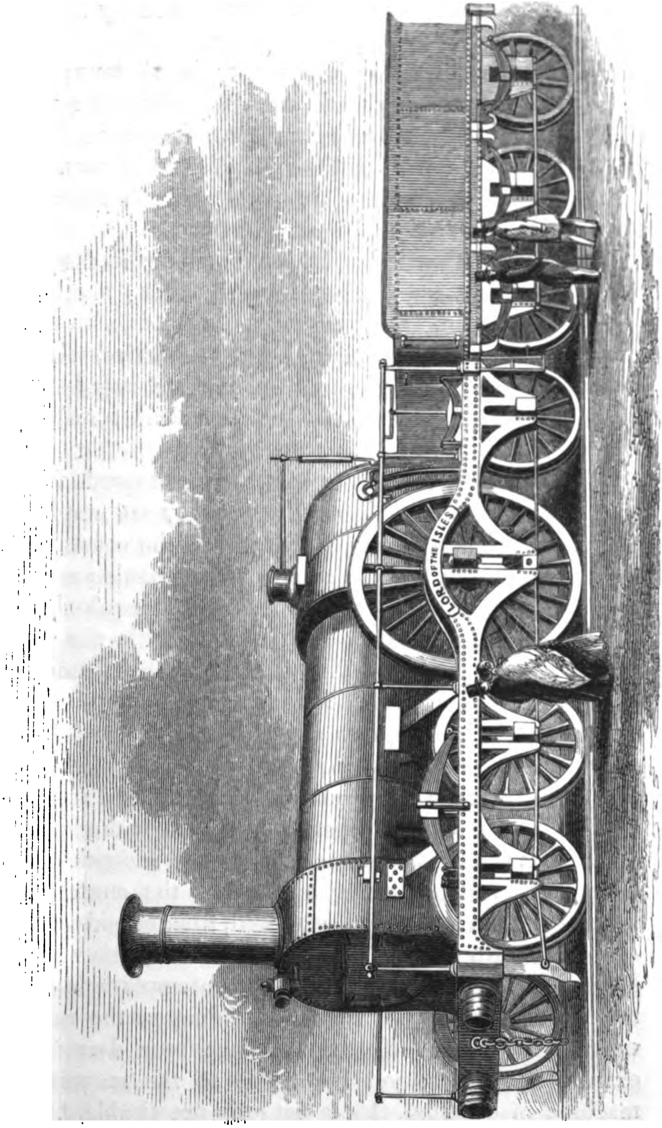
per hour; and of the 'Novelty,' with a gross load of nearly 10¾ tons, 15 miles an hour. The 'Novelty,' however, broke down more than once during the experiments; and the 'Rocket' alone accomplished the distance of 70 miles, the whole length of the trial run."

Such was the commencement of the construction of these wonderful machines, many thousands of which are now ceaselessly traversing this country, at a rate which would have been deemed fabulous at the date of the experiments in question.

Having produced these experimental engines in illustration of the early locomotives, we shall now select two of the best kind now constructed, as examples of the condition of this machine in our own day. Those we shall select were exhibited in 1851, by the Great Western Railway Company, and by the London and North Western: and the engines were respectively of the broad and of the narrow gauge construction. By this term is meant simply the difference in the respective widths of the rails on each line. The Great Western and most of its tributaries are on the broad gauge principle—the rails being very wide apart—and the London and North Western is on the narrow gauge principle, the interval between the rails being considerably smaller than in the former instance.

A magnificent engine was sent by the Great Western Railway Company to the Great Exhibition, which proved in every respect a model of power, speed, and safety. This locomotive is represented in the engraving, and is thus described in the Official Catalogue:—

"This engine is one of the ordinary class of engines constructed by this Company for passenger traffic since 1847. It is capable of taking a passenger-train, of 120 tons, at an average speed of 60 miles per hour, upon easy gradients. The evaporation of the boiler, when in full work, is equal to 1000 horse power, of 33,000 lbs.


LORD OF THE ISLES

per horse—the effective power, as measured by a dynamometer, is equal to 743 horse power.

"The weight of the engine, empty, is 31 tons; coke and water, 4 tons—engine in working order, 35 tons.

"Tender empty, 9 tons; water, 1,600 gallons, 7 tons 3 cwt.; coke, 1 ton 10 cwt.—total 17 tons 13 cwt.

"The heating surfaces are—fire-box 156 feet; 305 tubes 1,759 feet.

"Diameter of cylinder, 18 inches; length of stroke, 24 inches; diameter of driving-wheel, 8 feet; maximum pressure of steam, 120 lbs.

"The actual consumption of fuel in practice, with an average load of 90 tons, and an average speed of 29 miles, including stoppages (ordinary mail train), has averaged 20·8 lbs. of coke per mile."

The performances of these engines, as regards power and speed, are best exhibited when they are employed for the traction of express trains. In the course of a few miles, during which the rate of progression rapidly rises, the full momentum of the train is acquired, and the whole mass flies through the air with the most astonishing swiftness. The power of the ponderous engine, instead of diminishing in proportion to the demand made upon it, appears seldom in fact to be fully exerted, and increases with its exercise. On more than one occasion have we been carried along at a rate exceeding a mile in the minute. Yet even at the highest speed it has always seemed to us that a considerable degree of available power existed in the engine, the putting forth of which was repressed, from considerations of safety. No person can consider these facts without being filled with wonder in their contemplation. The time is yet recent in which travelling at the rate at which the swallow flies would have been deemed an extravagant fable; yet by means of the magnificent machine in question, this is not only practicable, but is

in fact daily accomplished on this line of railway. As regards speed, power, and safety, the broad gauge principle is unquestionably superior to the narrow gauge. But it is inferior in economy of first cost, and also of working. Its capabilities are fully tested on the lines now open, and its general superiority in all other respects may be admitted. But the narrow gauge is that which appears to have been adopted as a national standard, and it seems to be fully equal to all the ordinary requirements of railway traffic, while a high velocity is attained on it.

The London and North Western Railway Company, representing the narrow gauge railways, sent for exhibition one of their splendid express engines, built on Crampton's patent principle, and called "the Liverpool." This engine was awarded a Council Medal. The appearance of this engine is peculiar, in consequence of the large driving-wheels being placed behind the fire-box, the other six wheels, on which the engine is carried, being in front of it. The boiler is also extremely low, and the whole appearance of the machine gives the impression of great length, and of some awkwardness. The construction is however very efficient, and locomotives on this principle are found to work well. The diameter of the cylinders in this engine is 18 inches, and the length of stroke of the piston 24 inches. The diameter of the driving-wheels is 8 feet. The heated surface amounts to not less than 2,136 square feet, which is obtained by means of tubes, besides the surface exposed to the direct action of the heat in the furnace, which measures 154 square feet. The evaporation resulting from this vast amount of heated surface is stated to yield a steam power equivalent to that of 1,140 horses. This is greater than that obtained by the large engine of the Great Western Company, but it is to be observed that the *effective* power is not stated. It

would probably be found to be in reality inferior to the other.

One of the conditions of great speed in a locomotive is, that the piston should make the fewest possible number of strokes whilst the engine traverses a given space, for which purpose the driving-wheels must be the largest possible. By bringing these from their usual position, near the middle of the boiler, to the foot-board of the furnace, the inventor of the engine in question has obtained for his driving-wheels the large diameter specified, namely 8 feet. It is also found that by using large driving-wheels there is a less tendency to jump, in consequence of the centrifugal force of the wheel—a tendency which appears to have been the frequent cause of many serious accidents. The low position of the boiler of this engine is also a considerable advantage, as it has the effect of giving it greater steadiness. The weight of the machine is carried at its two extremities by the guide-wheels and the driving-wheels, and this assists to steady the engine. In Mr. Crampton's engine the driving-wheels are connected with the piston-rod, not directly, but by means of a connecting-rod, which is considered an advantage, as tending to take off the risk of concussions to the machine when meeting with slight inequalities in the road.

Another locomotive which attracted attention in the Great Exhibition was one sent by Messrs. Hawthorn, of Newcastle-on-Tyne.

This engine is mounted on six wheels; the drivers being 6 feet 6 inches, and the fore and hind wheels of 3 feet 9 inches in diameter respectively. The cylinders are of 16 inches diameter, and the stroke of piston 22 inches. The number of tubes, of brass, is 158, each of 2 inches external diameter, giving a radiating surface of 865·4 superficial feet, in addition to 110 feet of fire-box, making a total of 975·1 superficial feet. There is a

bridge across the fire-box, having an additional water space. All the framings, both inside and out, extend the full length of the engine, and are firmly connected together by strong iron double-knee brackets. The whole of the machinery was fitted and fixed entirely independent of the boiler, and, when completed, the wheels and axles being put into their proper positions, the boiler was fixed in its place, and firmly secured by bolts to the brackets already mentioned and to the outside frames. There are four novelties in this engine; viz. Messrs. Hawthorn's patent double compensating beams, their patent slide valves, their patent link motion, and their patent steam pipe. Instead of the six springs ordinarily used in locomotive engines, the builders of the 'Hawthorn' have introduced on each side of the engine two beams and two springs, by which a direct action is communicated at once to all the axle bearings, so that a uniform weight is constantly maintained on each of the wheels and axles, thereby securing a constant amount of weight upon the driving-wheels for adhesion, a matter of considerable importance. Secondly, the patent slide valves are placed vertically between the cylinders in one steam-chest in the usual manner. One slide valve has a plate, cast or bolted, upon the back, which is accurately planed, so as to be perfectly parallel with the face of the valve. The other slide valve has a box cast upon the back, into which is fitted a projection or piston, the face of which is also planed, so as to be parallel with the valve; it is packed in the most simple manner and made steam-tight, and then put into the steam-chest, as in ordinary valves. A passage is formed between the exhaust ports through the slide valves, thus giving a free discharge to the steam. These valves are relieved from one-half the pressure of steam, and, consequently, one-half the friction. Thirdly, the patent link motion is also introduced

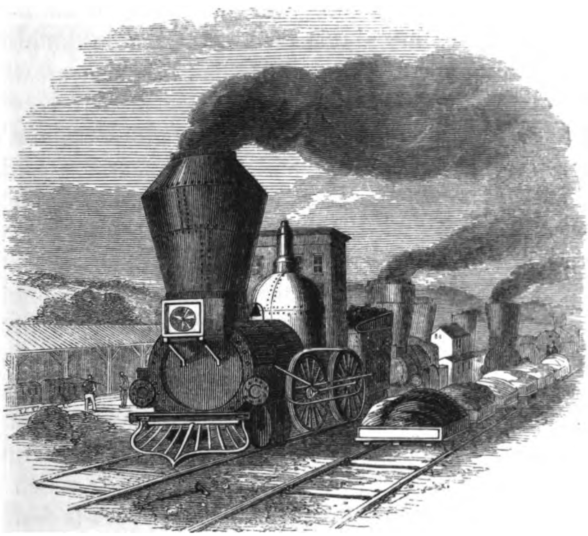
into the machinery of this locomotive. The expansion link, instead of being connected to the ends of the eccentric rods, and having to be continually raised up and down with them, is directly connected by an eye-joint to the slide rod, and there suspended; hence its weight is removed from the reversing gear. Having a fixed centre, the link requires less power to move and regulate the slide valves; the link is also much more durable, as the sliding-block is more than three times the length of the ordinary block. Lastly, their patent steam pipe is substituted for the domes and cumbrous projections on the top of the boiler; this pipe is fixed into the tube-plate of the smoke-box by a ferule, as in the case of an ordinary tube, and extends nearly the whole length of the boiler, being placed near to the top; it is perforated along its entire extent with small slits, so proportioned as to admit the steam into the pipe directly above the place of generation. This is a manifest improvement on the ordinary method, where the steam has to reach from all parts of the boiler to one or two orifices, as it is now conveyed to the cylinder in a purer state; moreover, *priming* is, to a considerable extent, avoided. Such is the inventor's own account of this powerful and useful machine.

A very useful kind of locomotive engine is that technically called a tank-engine. In this form of locomotive the tender is dispensed with, and the engine is made to carry its coke and water. In some instances the water is carried in semicircular cisterns placed above the boiler, and the coke in a space near the fire-box. These engines will carry sufficient fuel to run at high velocities on short journeys, and are found to be economical in their working, and sufficiently powerful for light passenger trains.

The railway system has undergone an immense development in the United States. The general construction

of the engines resembles our own, but the form of the chimney is peculiar, and in front is a curious arrangement called a cow-catcher, for removing obstacles off the road, cows, sheep, &c.

The practical failure of the application of the principle of atmospheric pressure to the propulsion of carriages on railroads renders it merely necessary to advert to it by a few passing remarks. The railroad to Croydon, although



a costly experiment, has certainly proved the possibility of employing compressed air as a source of mechanical power. A committee of the House of Commons has also expressed the strongest opinion in favour of the economy, speed, and safety of the atmospheric railroad. Its essential principles may be thus described:—A central iron tube ran along between the rails, the interior of which was smoothly turned, and received a piston which moved freely but air-tight within it.

This tube was exhausted of its air by powerful stationary steam-engines, and the piston was attached to the body of the carriage. On the starting of the train the vacuum produced within the tube caused the piston to move forward, and with it the carriage to which it was connected. In order to preserve the vacuum within the tube a leather valve was placed over it, which, after being lifted by the onward progress of the piston, was again sealed down by a wheel which pressed upon it. In this manner the train was pushed from station to station by the atmospheric pressure acting on the piston. After a prolonged and patient trial, this system, which had many advantages, but which also proved very defective in working details, was finally given up, and the enormous tubes, engines, and other apparatus sold at a great loss. Locomotive steam engines now fulfil the same duties to which the pressure of the air was formerly subjected.

In addition to the ordinary form of steam engine, which is essentially the same (consisting of a piston and cylinder, the former only capable of rectilinear motion) in high pressure and in low pressure engines, whether for purposes of locomotion by land or sea, or for the development of power for the manufacturer, ingenious persons have contrived other kinds which are sometimes used where great economy of space is desired. One of these is the disc-engine of Mr. Bishopp, which is employed in driving the powerful printing-machines at the *Times* newspaper-office. The arrangements of this engine are not easily explicable without the assistance of diagrams, and even with such aid it might be scarcely possible for the reader to form a clear conception of the working of it. Externally it appears like a semicircular iron box, on either side of which an axis projects connected by a bow of metal above, and attached to the crank of the driving-shaft by an ingenious

arrangement. In its action it resembles the movement of a man's arm working a barrel-organ. This kind of engine has been used for screw-steamers, and appears to be an efficient and economical machine. It was exhibited in motion at the Great Exhibition, and attracted much notice by the peculiarity of its appearance.

Another engine referrible to this class of prime movers was also shown on that occasion, and was applied to actuate several machines. This engine was invented by Messrs. Davies, of Tipton, in Staffordshire. It had two cylinders side by side, and coupled together into one long one. Each piston is an elliptical disc, fitted on to a spherical part of the one axis at a considerable angle, and revolving continuously forward, its edge moving in a groove in the cylinder. The simplicity aimed at in the rotary principle of engines was carried into the governor of this engine, and afforded a very neat arrangement. Instead of the two balls ordinarily used at the ends of arms, there is in this engine but one ball, revolving on its own axis. On this ball is fixed a ring or zone of metal, heavier on one side than the other. The consequence is, that when the engine is going slowly, the centrifugal force is not sufficient to overcome the gravity of the heavy side, and the ring is at a considerable angle with the horizon; but when the speed is increased, this same force acquires so much more power that the heavy side flies out towards the horizon, and in so doing rises ~~at~~ the same time, so that the ring is nearly horizontal. The connexion with the throttle valve is made inside the ball, and passes down the hollow spindle on which the ball is supported, and by which it is driven. It is very efficient, and where space is an object, it is particularly applicable; and even under other circumstances its great simplicity will probably cause its frequent adoption. The singular appearance of this governor, resembling Saturn and his

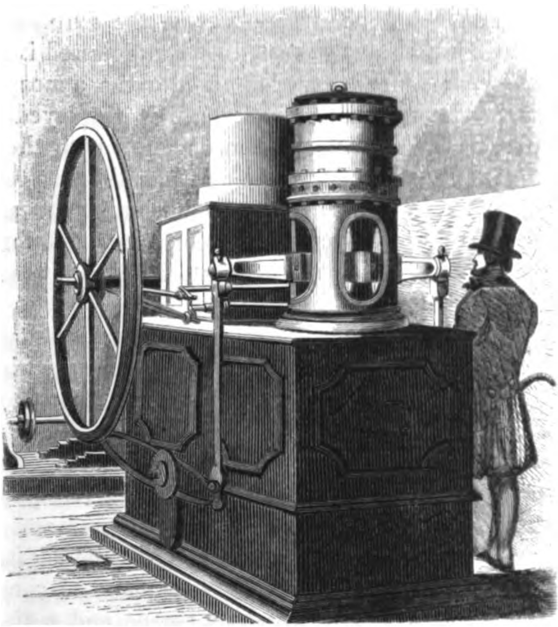
ring in its outline, attracted much notice, and there was every reason to believe that it was a good and useful form of this most essential part of a stationary engine.

Messrs. Simpson and Shipton's short-stroke engine may be also referred to this class of machines, and was exhibited at work in a model of a ship propelled by a screw. A full-sized engine was also at work driving Messrs. Parr, Curtis, and Madeley's cotton machinery. This engine is very compact, and is capable of running at very high velocities. In appearance it is singularly solid and massive, and it performed its duties with apparent ease. This engine is something between a rotary and reciprocating engine, the piston revolving inside the cylinder, but still attached to the crank-shaft by connecting-rods.

Having thus fully discussed the application of steam as a prime mover in the various machines which engineers have adopted for concentrating and directing its force, it is necessary to allude to some other, and although less important, still valuable sources of mechanical power. The pressure of the atmosphere for working railways has already been noticed. In addition to the plan thus proposed it has been suggested to drive engines on similar principles to the steam engine by means of compressed air. One of the most feasible of these plans has been to charge certain strong vessels with air at an enormous pressure, and to connect these vessels with a locomotive engine. The piston would of course be acted on by the pressure of the air, and would propel the machine. But a very little consideration would serve to show the impracticable nature of all these plans for general purposes. The risk of charging the vessels, the rapid exhaustion and increasing loss of the propelling force, the leakage, and the inconveniences inseparable from its working details, might all have sufficed to convince any person not pos-

sessed with the absorbing spirit of inventive ingenuity, that such a plan is totally inapplicable for all useful objects, however pleasing as a model in a lecture-room or in the workshop.

Great attention has very recently been excited by the air or caloric engine of Ericsson. One form of this engine was shown at the Great Exhibition, and is shown



in the cut. The engine has since been tried on the large scale, and a vessel has been fitted up for marine service with one on this construction in America.

"This invention," says Mr. Ericsson, "consists in producing motive power by the application of caloric to atmospheric air or other permanent gases or fluids

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susceptible of considerable expansion by the increase of temperature; the mode of applying the caloric being such that, after having caused the expansion or dilatation which produces the motive power, the caloric is transferred to certain metallic substances, and again retransferred from these substances to the acting medium at certain intervals, or at each successive stroke of the motive engine; the principal supply of caloric being thereby rendered independent of combustion or consumption of fuel. Accordingly, whilst in the steam engine the caloric is constantly wasted by being passed into the condenser, or by being carried off into the atmosphere, in the improved engine the caloric is employed over and over again, enabling me to dispense with the employment of combustibles, excepting for the purposes of restoring the heat lost by the expansion of the acting medium, and that lost by radiation also, and for the purpose of making good the small deficiency unavoidable in the transfer of the caloric."

We extract the following short and popular statement of the general principles of the engines employed in the vessel, the *Ericsson*, from the pages of the *Athenæum*, of Feb. 19, 1853:—"The grand feature by which this engine is distinguished from the steam engine, and all other power machines, is this,—that the same given quantity of heat which sets it in motion is used over and over again to keep up that motion; and that no additional supply is wanted beyond what is requisite to compensate for a small loss incurred by escape and radiation. This description involves the principles applied in the large engine fitted to the ship *Ericsson*. Two or three attempts have been made in this country to employ heated air; but Stirling's engine, which was in all its main features similar to Ericsson's, was the only one that approached success. It must be remembered that two caloric engines have been for some time at work in

the foundry of Messrs. Hogg and Delamater, at New York,—one of five, and the other of sixty-horse power. This larger experiment, therefore, is made with all the advantages derivable from practice and long-continued experiment.

"We must endeavour, within a short compass, to describe the caloric engine now at work. There are two cylinders, one of which is double the capacity of the other,—so that, the air which fills the smaller one being forced into the larger, and heated to about 480°, fills it also. Now this air in expanding exerts a mechanical force equal to moving the machinery, by raising the piston through the whole length of the cylinder. This heated air then escapes, the piston descends, cold air is forced in, and by its expansion another impulse is given to the machine,—and so on continuously. This operation is analogous to the practice of working steam expansively, air being employed instead of steam.

"Capt. Ericsson has introduced an entirely new feature, under the name of a *regenerator*, by which he purposes using the same heat over and over again. This *regenerator* is composed of wire net, sheets of which are placed side by side, as in the *Ericsson*, to the thickness of twenty-six inches. The heated air which has performed its duty escapes at a temperature of 480°. This passes through the innumerable meshes of the wire gauze of the regenerator, each layer of which deprives it of some heat; and when it passes out of this arrangement, it is reduced to the temperature of the external air nearly. Now, by a mechanical contrivance of no very complex character, which we need not describe, the air contained in the smaller cylinder is driven back through the regenerator; and in passing its interstices is said to take back the heat from the wire, and passes into the large cylinder at a temperature of 450°, having reduced the temperature of the wire in its passage to its former cool

state. Thus, the only fire necessary is that required to supply the waste of 30° which is lost in the operation. The ordinary respirator will convey a correct idea of the action of the regenerator,—the warm air passing outward warms the wires, and the cold air flowing inward takes this heat back from the wires again."

It will be apparent that in this engine *heat* in a peculiar manner is made the moving force; hence the correctness of the name employed—the caloric engine—which we may fairly expect in a short time to see ploughing the Atlantic Ocean. Whether the immense size of the cylinders required will prove an insurmountable obstacle to its application, time alone can determine. The *Ericsson* has four open cylinders, each of 168 inches diameter, with pistons of upwards of 22,000 superficial inches area, moving up and down through a space of six feet. Several trials have been made in the bay of New York, which appear to have been satisfactory; but we learn from private sources on which we can depend, that before the *Ericsson* is likely to achieve the Atlantic voyage, cylinders of twenty feet diameter will probably be substituted for those at present employed. We cannot but think that the present experiment is destined to open up some new applications of heat as a motive power, which will probably ere long supersede our best steam engines.

A lively interest has been excited among the engineers of this country as to the practical value of this invention, and it has on more than one occasion been declared to be inapplicable to the purposes of ocean navigation. Since the principle has been actually at work in large stationary engines, and since experience has proved its utility, it would appear at present rash to conclude that it is valueless for marine purposes. It is, at all events, very important to encourage every attempt to obtain an economical source of power for ocean steamers, since the

cost of such enterprises exceeds the gain, and they could not be carried on but for government aid. The caloric engine at the Great Exhibition was not in movement. It would have excited the liveliest interest had such been the case; in its inactive condition it was passed, by most persons, with scarcely any attention. From our own examination of this engine, we were favourably impressed as to its capabilities, and it was certainly a good specimen of American engineering in its working details.

Other vapours besides that of water (steam) have been used for the production of mechanical power as prime movers. The only form of engine to which our attention need be directed is one of the most recent, and also one of the most successful of these machines. It is a combined steam and ether engine, and was described before the last meeting of the British Association for the Advancement of Science, held in September, 1853, by Mr. G. Rennie. He states that this engine, invented by M. Dutromblet for the combination of ether vapour and steam, is now applied in propelling a ship from Marseilles to Algiers. There are two cylinders, of different diameters, into one of which ether vapour is admitted, and into the other steam,—the two motive agents being kept entirely distinct. The steam engine acts on the condensing principle, and the heat given out by the steam when admitted into the condenser is employed to vaporise ether contained in surrounding chambers. As ether boils at a temperature of 100°, at which water is condensed very efficiently, the act of condensing one fluid vaporises and gives expansive power to the other; and by using the ether vapour in a separate cylinder, and again condensing it in tubes cooled by sea water, a double action is obtained. Mr. Rennie had been requested to investigate the efficiency of the engine, and for that purpose he made a voyage in the vessel from

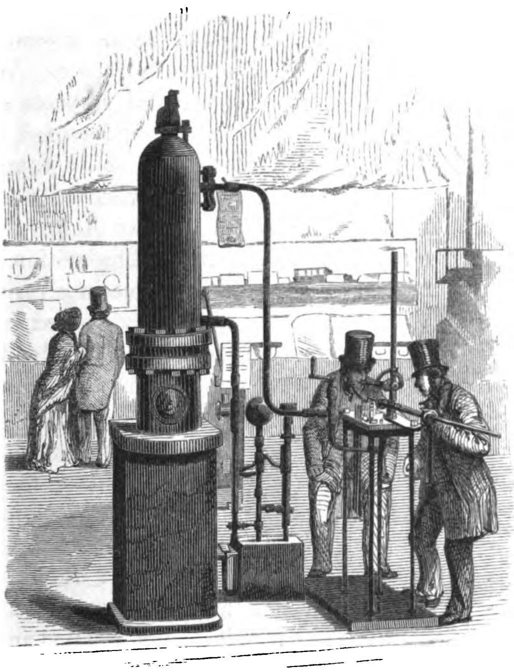
Marseilles to Algiers and back, accompanied by his son. The steam-boiler is adapted only for an engine of thirty-horse power, and during the return voyage Mr. Rennie placed the coals under lock and key, so that he might ascertain exactly the quantity consumed. The result of his investigations was, that by the additional action of the ether vapour there was a saving of from sixty to seventy per cent.; and the amount of gain had been reported by a French commission, appointed to examine the engine, at seventy-four per cent. The loss of ether by leakage did not exceed in value one franc per hour during the voyage, and that might be greatly reduced by improved construction in the machinery. The French Government have paid the inventor a very large sum for the invention, and there are now several ships in course of construction to be propelled by engines of this kind; one of which is to be of 1500 tons burthen, and the engines are to be of 150 horse power. Mr. Rennie said that arrangements are made for dispelling the ether vapour that escapes, so that there is no danger of its ignition.

Notwithstanding the high authority of this engineer, we must confess our own unwillingness to believe in the general advantages of any machine worked by the expansion of a vapour like ether—both injurious in its ultimate effects on the constitution of the engineers and stokers, and also inflammable and explosive in a very high degree. However safely such might work under the vigilance of those interested in its success, it is scarcely possible that accidents should not occur when, by long use, those entrusted with the care of the machine have become negligent; and, if an accident were to arise, it must necessarily be attended with very deplorable consequences.

The expansive force of steam has been applied by Mr. Perkins to other purposes than those of mechanical

motion. The steam-gun, shown in the cut, was formerly publicly exhibited, and is again attracting attention under our present unhappy circumstances of warfare.

The force of moving air has been applied to the production of mechanical force in a variety of ways. But these are so familiar in their general character, that it is

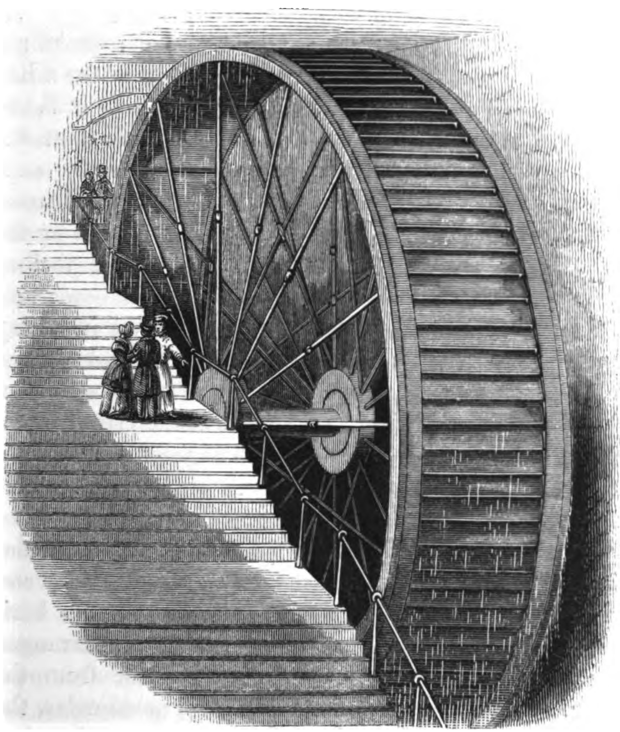


unnecessary minutely to notice them. Windmills, of both the vertical and horizontal construction, have been and still continue to be used, and certainly form an economical source of power. Those of the vertical kind are, however, much more powerful than the horizontal, and are consequently principally employed. The active

force of these machines, under the pressure of a brisk wind, is very large, and could reliance be placed on its constancy windmills would supersede steam engines in many instances. But the inconstancy of the moving power precludes such an application, and steam is very frequently used at large flour mills to drive the machinery when the wind is incapable of moving it.

The same general remarks are also applicable to the use of water in a moving state, as in rivers, from mountain streams, from the effects of tides, &c. Water-wheels, like windmills, are in essential respects simple constructions; and it may be easily understood that a moving body, such as a current of air or of water, impinging on the circumference of a wheel fitted with boards set in a plane opposite to that of the moving force, would tend to drive it round. The motion being once obtained, is of course communicable in a variety of ways from the axis of the wheel, as by cogged wheels, by cranks, by straps, couplings, &c. It may be useful, perhaps, to state that water-wheels are generally constructed on one or other of the following principles:—either the water strikes the floats of the wheel horizontally, or at a slight inclination downwards, touching them only on the under part of the wheel—which is called an undershot wheel; in which case the water drives the wheel by its impetus rather than by its weight—or when the water acts by its weight upon the floats of the wheel; in which case it is called an over-shot-wheel. One of the largest water-wheels applied to manufacturing purposes is on this principle. It was erected at Ashworth's cotton-mill, near Bolton, in Lancashire. This wheel is sixty-two feet in diameter, it is of 150 horse power, and was built at an expense of about 5,000*l.* It is represented in the annexed cut. The models of a pair of magnificent water-wheels were shown at the Great Exhibition in 1851. The originals are at

work at the mines of the Devonshire Great Consolidated Copper Mining Company. They are of 140 horse power each, and were erected at the mines of that company for the purpose of pumping water from the one shaft by a plunger, and from the other by a drawing lift. The first of these is a wheel, 40 feet in diameter, by 12



feet in breast, pumping from the depth of 115 fathoms, or 690 feet, with 14-inch pumps, 7 feet 6 inches stroke, discharging 60 gallons of water per stroke, and lifting at each stroke 69,000 lbs., the average velocity being 4½ strokes per minute. This wheel works a line of 3¼ inch round iron rods, 390 fathoms, or 2,340 feet, over pulleys,

ascending a hill, at an elevation from the wheel to the shaft of 384 feet above the wheel. This wheel pumps the water from the mine called "Wheal Josiah."

The other wheel is 40 feet in diameter, by 12 feet in breast, pumping water from a depth of 80 fathoms; 60 fathoms, or 360 feet, with 12-inch pumps; and 20 fathoms, or 120 feet, with 20-inch pumps, 6 feet stroke, discharging 98 gallons of water per stroke; it lifts at each stroke 40,600 lbs. This wheel works a line of rods of $3\frac{1}{4}$ inch round iron, 520 fathoms, or 3,120 feet, over pulleys, in connexion with the shaft at the mine called "Wheal Anna Maria." The water supplying these wheels is derived from the river Tamar by the means of a canal two miles long, and from the water collected from the dressing floors of the various mines.

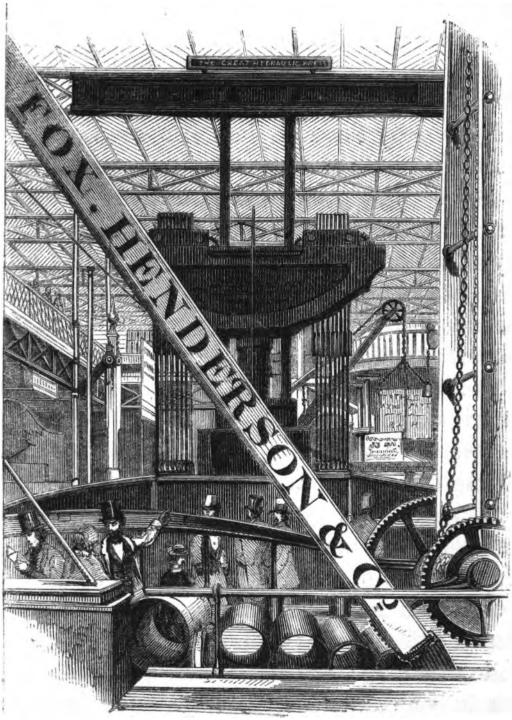
Water has also been used as a prime mover in a very ingenious manner, and with great effect and advantage, in the machines called turbines. A very fine specimen of one of these machines was shown at the Great Exhibition, and was rewarded with the highest approbation of the jury, in the form of a Council medal. This engine stands in an independent framing, and is, consequently, easily put up, and requires but little foundation, beyond what may be necessary for its stability and resistance to strain. It consists essentially of a horizontal water-wheel, the apertures of which are arranged so as to receive the most effective impulse from the water. The shaft of the turbine is perpendicular, the compartments for the exit of the water being placed at the bottom, and the motion being led off at the upper part of the vertical shaft. This engine is capable of running at very high velocities, from 100 to 200 revolutions in the minute, and is, consequently, applicable for driving machinery without any accelerating gear. Two large engines on this principle have been fitted up at

the furnaces of Rachecourt-sur-mare, near St. Didier. The fall of water here was, at the most, only three or four feet, and sometimes was not more than two feet. The engines were placed underground beneath the flatting mills, and were each fed by a separate canal of sixteen feet three inches wide. To have obtained a similar power—namely, that equal to 140 horses—under the same conditions of height of fall of water, with an undershot water-wheel, would have required a canal ninety-seven feet six inches wide. The maximum effect obtained by these engines has been stated to be from seventy-eight to seventy-nine per cent. The engine at the Exhibition was furnished with an ingenious arrangement of Watt's governor, by which its velocity was capable of being regulated. It was also composed of several compartments, by which an increase or diminution of power might be obtained. These engines are applicable to tidal rivers, where a low and variable fall only is obtainable, and they have been used with much advantage in many places in France.

The following are the principal advantages of this form of engine:—It occupies a small space. Revolving very rapidly, it may, when used for grinding flour, be made to communicate the motion directly to the millstones; it works under water; it works equally well with small and with large falls of water; it yields a large useful effect, equal, if not superior to that of most hydraulic machines; and the same engine may be made to work at very different velocities without materially altering its useful effect. This last property is one of great importance in certain applications, and constitutes an advantage of this machine over most others that have their established rates of working, from which it is not possible to deviate without a proportionate sacrifice of power.

Water-engines have also been constructed in princi-

ple not differing from the steam engine: that is to say, a column of water has been made to act upon a piston within a cylinder of the same general construction as those of the steam engine. The most valued application of water, however, and that to which our attention is now to be directed, is in the hydraulic press—an in-

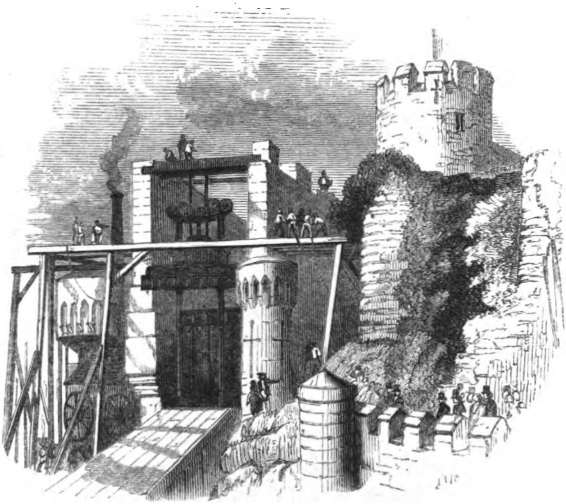


strument of power only limited by the capabilities of engineering skill to give the means for its development, and capable of such a wonderful variety of application as to be fit for the compression of a few bales of pocket-handkerchiefs, or for the elevation of such a stupendous structure as the iron tube of the Menai.

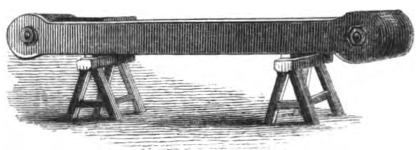
Proceeding upon the well-known law of hydrostatics, that the particles of water and other fluids, when confined, press on the vessel which confines them in all directions,—and upon its result—namely, that pressure exercised upon a small column of water, when conveyed through it to a larger body of water, propagates itself throughout the whole mass—the hydraulic press has been ingeniously constructed. This press consists essentially of a force-pump, to which is attached a strong pipe with a very fine bore, connected with a powerful cylinder, into which the water is forced, and driven up a metallic piston working perpendicularly in it. If the piston of the force-pump is pressed downwards with a force of 100 lbs. and the large piston has a surface 1000 times larger than it, then the pressure exerted on the large piston will be 1000 lbs. Thus a man of moderate strength can, by this instrument, exert a degree of force only limited by the size of the large piston and cylinder, and by the resistance of the materials of which the press is made.

Engineers and manufacturers have largely availed themselves of this wonderful power, and the hydraulic press now constitutes one of the indispensable machines of ordinary use. The same force has also been used for a variety of purposes, for lifting heavy bodies, for cranes, as well as for producing the most powerful compression. One of its most interesting applications, however, was very fully illustrated, and at great cost to the proprietors, at the Great Exhibition of 1851, in the great hydraulic press used for raising the iron tubes over the Menai Straits. This machine, represented on the last page, was shown, not in model, but in the original, by the spirited proprietors of the foundry at which it was made. A valuable and instructive account is given of it in the Official Catalogue, from which we compile the following facts. It may be useful to preface them by the following

explanation. The press was formed, as usual, of a large cylinder of iron, and a piston called a ram. It was, when applied to raise the tubes, as represented in the cut, placed on iron beams or girders, firmly secured by



machinery at the upper part of the tower, and chains connected with the head of the ram descended from it to be fixed to the immense tube they were intended to



elevate. Now, it is obvious that, if the piston or ram was pushed up by water forced into the cylinder, it would lift these chains, and as these were firmly secured to the tube, it also would be lifted. One of the links is

shown in the cut. As the tube was lifted, a solid bed of masonry was built under it: and it was thus, by a succession of lifts, each time rising six feet, and occupying from thirty to forty-five minutes for its accomplishment, finally triumphantly raised and secured in its proper place. All the tubes were thus elevated, and now maintain their giddy height; wonderful monuments of the power of the hydraulic press, and of the skill of the engineers who devised this method of accomplishing so arduous a task!

To cast the cylinder, it required 22 tons of fluid metal, the additional quantity beyond its finished weight being required for the head or git, which weighed 2½ tons. This head, or git, was kept in a fluid state for six hours after the run, by replacing the material, after it became stiff, with metal fresh from the furnace, and of the highest attainable temperature, for the purpose of supplying the space in this immense body of metal below, consequent upon the contraction. In three days afterwards, the cylinder was partly denuded of its outer coat of sand, when it was found red hot; in seven days, it was lifted from the pit in which it was cast; and in ten days, or 240 hours, it was sufficiently cool to be approached by men well inured to heat, for the purpose of dressing the remaining sand off it.

The greatest weight lifted by the press at the Britannia Bridge was 1,144 tons; the quantity of water used for each 6-feet lift, 81½ gallons. "The pressure at 3 tons per circular inch equals 3·819 tons per square inch, which would raise a column of water 5·41 miles in height; this pressure would, therefore, be sufficient to throw water over the highest mountains on the globe." This extraordinary fact is derived from Mr. Edwin Clark's work on the Britannia and Conway Bridges. The following additional extract shows indirectly the vast power of this machine:—

"If it were required that 1 lb. should raise the tube, or 2,000 tons, then one arm of the lever must be 448,000 times as long as the other; but if the 1 lb. move through a space of 1 inch, the tube will be only lifted $\frac{1}{448000}$th part of an inch; and in order to raise the tube 100 feet, the pressure of 1 lb. must be continued through a space of 83,522 miles; and conversely, a pressure of 2,000 tons, through a space of 100 feet, would raise 1 lb. 83,522 miles. Thus the descent of a clock-weight through a space of 6 feet overcomes the friction of the machine, and moves the extremity of an ordinary seconds-hand through a space of two miles in a week, and the descent of the tube to the water would maintain the going of an ordinary clock for 240,000 years;" or the power expended by the press in lifting the tube 100 feet, if applied to an ordinary clock, would work it for a period of 240,000 years.

After the first tube was raised, the cylinder met with an accident, described in the following terms by Mr. Clark:—

"In a little more than a fortnight after this operation the presses were removed, ready for raising the next tube. They were lowered and raised again by means of capstans, with an 8-inch rope; and in this operation another accident occurred with the unlucky press. The cylinder was lowered from a cat-head at the top of the tower; the rope from the blocks led to a capstan on the beach, on which three turns only were taken; and while the cylinder, weighing 15 tons, was suspended at an elevation of 140 feet above the water, the rope unexpectedly surged on the capstan, and was dragged out of the hands of the men who were holding it; the cylinder descended with fearful velocity, dragging the rope through the block-tackle and round the capstan, which fortunately became palled by the jerk. As the velocity increased, the cat-head in the tower gave way, and the cylinder fell on the stone shelf below, fracturing the

masonry, and gliding off 50 or 60 feet into the Straits. Several men were injured, and a sailor who was serving out the coil of rope was dragged round the capstan and killed. None of the tackle was broken, and the press was easily raised by the ropes attached to it, and was found to be uninjured by the fall."

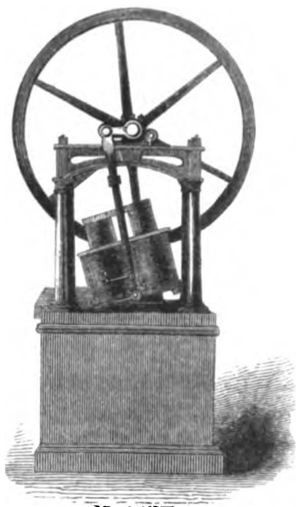
The thoughts of engineers and philosophers have long been directed to the remarkable force termed electro-magnetism, as offering a new and valuable source of mechanical power, and a variety of machines have been constructed for the purpose of developing, applying, and illustrating this force. Some of these we shall briefly notice; but it is necessary, first, to give some account of the force itself. It was discovered by Oersted, that when a voltaic current passes round a piece of soft iron, by means of a coil of copper wire, the iron, which had no magnetic properties before, now becomes a most powerful magnet, and is capable of sustaining an immense weight by its newly acquired attractive force. Immediately, however, that the current is broken, all this immense power suddenly disappears, and the iron which before sustained some hundred pounds, now will not lift a needle! It is obvious that in this property—so suddenly acquirable, and so instantly annihilable—reside the elements of a motive force, the application of which only requires a little ingenuity of arrangement. If this piece of iron, with its galvanic coil, could be so arranged in a machine as in successive alternations to draw forward some moving portion which might be attached to a crank, shaft, and driving-wheel, then we should have a practical application of this force for the production of mechanical power. A piece of iron thus circumstanced is called an electro-magnet; for its magnetic properties are entirely due to the passage of the voltaic current through the wire around it; and the magnetic state is said to be *induced* in the iron, and it

becomes a magnet, by *induction.* The science which investigates the laws of this remarkable force is called electro-magnetism.

Numerous attempts have been made to apply electro-magnetism as a power for moving machines—and among other philosophers, by Professor Jacobi in Russia, and Professor Wheatstone in this country. Professor Jacobi for a long series of years carried on his experiments, and finally succeeded in applying an electro-magnetic engine to the propulsion of a vessel, which moved under its influence at the rate of about four miles an hour. These experiments certainly demonstrated the possibility of the employment of this force even on a large scale; but after a great expenditure of time and of money, in which the philosopher was supported by the Imperial Government, he finally abandoned the attempt, and electro-magnetism as a motive power was evidently considered by him as an impracticable thing—at least, in comparison with the steam-engine. And, after more or less success, such is the result to which most of those who have attempted to apply this force have been compelled, however unwillingly, to arrive. Recently, however, M. Soren Hjorth, a native of Denmark, and Professor Page of the United States, have appeared to revive the prospects of a practical and economical application of electro-magnetism as a motive agent.

M. Hjorth's engine is represented in the accompanying cut. The engine consists of two hollow cylinders of soft iron in connexion, side by side, forming together a complete electro-magnet—these are surrounded by coils of wire, in which work two pistons of soft iron, also surrounded with coils of wire, forming another electro-magnet; the consequence being that, on passing the galvanic current, both cylinders and pistons mutually attract each other with great force. The two pistons are attached to a crank on the driving-shaft by a con-

necting-rod, and the cylinder magnets oscillate in a similar manner to oscillating steam-engine cylinders.



At the other end of the shaft is a similar arrangement; the positions of the cranks, while in motion, always being diametrically opposite to each other. The conducting wire from the battery leads to two metal springs, on which a point, in connexion with the iron cylinders and pistons, completes and breaks the circuit at every stroke —thus alternately making each series of magnets the moving power, and keeping up a regular and continuous motion.

The principal feature of importance, from the specification of the patent, is that of passing moveable magnets into hollow magnets, the interior of which is conical, and also placing a number of rods or points of different lengths in the hollow magnets, which rods pass through corresponding apertures in the moveable magnets. The consequence of this arrangement is, that the respective magnets mutually attract each other by the superficial approximations of their several parts, which, during the whole stroke, present themselves, at different points, at the poles of the magnets, thus exercising their power with a direct force, without being limited to any length of stroke, since that depends on the number of rods employed. To prevent the destructive effects to the machinery of the electric spark, which has been found to be great when developed with any intensity, the patentee arranges the communicator and current

alternator in such manner that the electric fluid is, according to its intensity, divided into several separate currents, which pass round the respective magnets without communicating with each other; and, by keeping the points of contact slightly moistened with a dilute acid, no actual spark is brought out on completing the circuit.

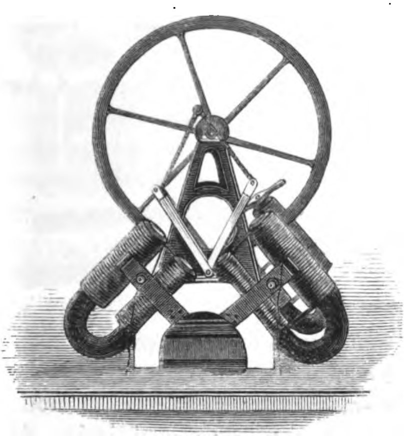
The patentee proposes, in applying this principle to locomotive engines, to magnetise the wheels by magneto-electricity, produced by their own revolution; and the required adhesion thus gained will enable light engines to draw an enormous weight. That there is a mighty power in store for the use of man in the hitherto inextricable mysteries of electricity, we have long believed; and the continuous, the almost daily, discoveries which are made, lead us to infer that such belief is founded on reasonable grounds.

From the accounts of the American experimenter, Professor Page, it would appear that his engine is constructed on principles similar, if not identical, to those of M. Hjorth. His engine is thus described. It was an upright engine of two-feet stroke; two bars of soft iron, six inches diameter and three feet in length, were the prime movers, and these were balanced, by means of connecting-rods and cranks, upon a fly-wheel shaft. The balance-wheel and shaft together weighed 600 pounds. When this engine was tried with a battery which had before given one-fifth of a horse power, with a smaller engine, it produced only one-third of a horse power. By attention to the adjustments, and particularly to the cut-off, the engine yielded one-horse power. By daily improvements, this engine yielded, with a trifling increase of battery, a full two-horse power.

In order to give a practical character to this machine, it was placed in connexion with a circular saw of ten inches diameter, a turning lathe, and the grindstone

of the workshop, all of which it worked simultaneously. After many trials with this engine, its parts were taken down, and used in the construction of another of a rather different arrangement. In the new form, the engine is said to have again increased in power, to the extent of one-half; and by the aid of a few feet more battery surface, the power was found to be above four horses.

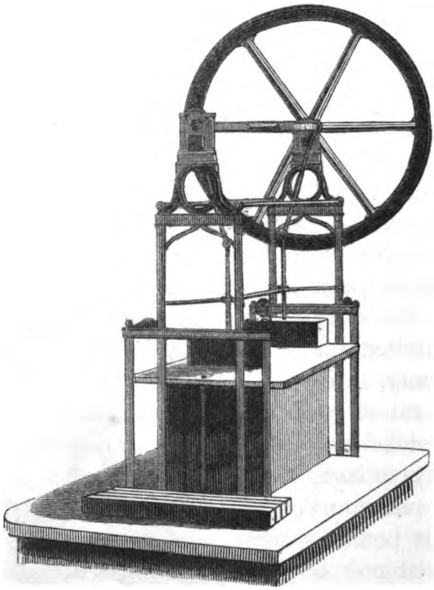
With a view of exhibiting the active force of one of his engines, Professor Page gave it the following trial. The crank was placed at half-a-stroke, and a hook was put over it, to which was attached a long rope; three of the strongest men of the party then took hold of the rope, two of them having their feet braced. The three men could not start the engine a hair's breadth; four of the men then took hold, and they moved the crank two inches, where it stuck fast; the power was then let in, and the engine started and made a speed of ninety revolutions in a minute. At a recent lecture at Washington, Professor Page exhibited his trip-hammer, in which he raised up and suspended an immense bar of iron, weighing one hundred & fifty pounds, which produced a jarring of the whole room as it fell. Heavy blows were made in rapid succession; but the motions of the bar were so easily controlled that it was laid down slowly or let to fall rapidly at pleasure.



An interesting and simple electro-magnetic engine, shown in the cut, was exhibited, which operates simply

by attaching a chain to the armature of the magnets, and connecting it with a crank and fly-wheel. The arrangement is certainly ingenious, but is not adapted for the large scale.

There were many other varieties of electro-magnetic engines at the Great Exhibition. One of these, shown in the cut, resembles M. Hjorth's in its gen ral arrangements.



In concluding the present chapter, it may be useful to contrast the comparative economy of steam and electro-magnetism, as sources of motive power. From what has already been stated, it is evident that the problem of obtaining, from the electro-magnetic force, an available amount of motive influence, has already been solved. The question upon which ingenious men are now occupied is not, therefore, the construction of a machine

capable of being put in continuous motion by this force, but to determine its relative cost, comparatively with other sources of mechanical power; for if it can be shown that electro-magnetism is less economical than steam, it is very improbable that it will ever come into general use for practical purposes of mechanical motion. Up to the present moment, it is admitted by all that no electro-magnetic engine can compare, in point of economy, with a well-constructed steam-engine. Mr. Toule has shown that to maintain a power of one horse, in an electro-magnetic engine of the best construction, and with a battery of the best kind, it requires the consumption of forty-five pounds of zinc. Now, it appears that a single grain of coal, consumed in the furnace of a Cornish engine, lifted 143 pounds one foot high, whereas one grain of zinc, consumed in the battery, lifted only 80 pounds. The cost of one hundredweight of coal is under ninepence, but the cost of one hundredweight of zinc is above 216 pence; therefore, under the most perfect conditions, electro-magnetism must be nearly twenty-five times more expensive than steam power. And from other data, derived from the disturbing influence over the power of the magnets, produced by the movement of them or their parts, this loss is still further increased. At present, therefore, the subject remains just in this position; and, it must be confessed, there is little prospect of its assuming a different aspect. If the time should ever arrive when it can be shown that electro-magnetism is less costly than steam, then this wonderful force will usurp the present place of the steam-engine—will fly along the iron road, or across the ocean—and will toil in the manufactory and in the mine.

CHAPTER III.

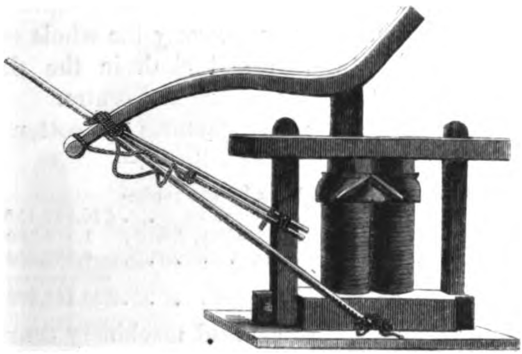
MANUFACTURING MACHINES.

SECTION I.—TEXTILE PROCESSES.

A VERY interesting department of industrial science is introduced to us under the subject of our present and some following chapters. In preceding portions of this work, the reader has been made acquainted with the elements out of which mechanism is constructed, and also with those wonderful arrangements of working parts which, as a whole, constitute prime movers. The inert metal has been displayed as endowed by human skill with automatic movement and superhuman force; and it now remains for us to exhibit a still greater marvel, if that be possible—namely, machines representative of man himself engaged in industrial labour. Having succeeded in developing an unlimited source of motive power, man's next concern is to construct machines capable of taking his own place, and of supplying his wants.

From the earliest times, the production of textile fabrics has constituted a very important part in industrial economy. The necessity for such articles, for clothing and for domestic use, rendered it essential to comfort, if not to existence, in a civilized state, that

they should be produced in sufficient quantity to be generally available for use. This could only be accomplished by mechanical means. The mere labour of the hands would be quite inadequate to the required purpose; and the spinning-wheel and the loom, of simple forms and clumsy construction, are among the earliest of all manufacturing machines. The cut represents a Hindoo cotton gin, employed for removing the seeds from the cotton.



The history of these simple but ingenious machines is so familiar to most persons, that it is not necessary here to advert to it, nor to discuss the gradual progress of improvement in their construction. Our attention will be occupied with a description of the most perfect systems of producing textile fabrics now known. The whole subject naturally arranges itself under two general divisions; the first of which relates to the production of the thread, whether of cotton, wool, silk, or flax, and the second to the fabrication of the thread into woven tissue.

The Manchester manufacturers, and those of its immediate vicinity, have most successfully prosecuted this department of industry; and there is no other district in the world in which such an amount of mechanical skill is concentrated upon the treatment and manu-

facture of cotton, from its state as imported to the production of the perfect fabric. The statements which follow will illustrate this fact, and are derived from a paper put forth by the Manchester manufacturers at the time of the Great Exhibition.

An idea of the Manchester trade will be best conveyed by stating the quantity of cotton delivered at Liverpool for consumption, which is now about one million and a half bales annually; and as they average about 400lbs. each, it gives the enormous weight of six hundred million pounds; and nearly the whole of this is manufactured into yarn and cloth in the district of which Manchester is the capital and centre.

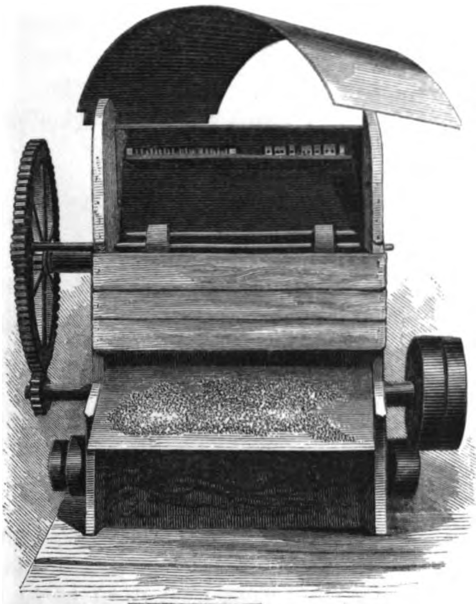
"Our exports of cotton manufactures and cotton yarn, during the year 1850, were as follows:—

Cotton manufactures entered by the yard—	
1,358,238,837 yards, declared value . . .	£20,528,150
Of other descriptions—lace, hosiery, &c. .	1,343,780
Cotton-yarn—131,433,168 lbs.	6,380,948
Total declared value	£28,252,878

The object of all the beautiful machinery connected with the first part of the preparation of cotton, prior to its being converted into thread, is to render the fibres clean and free from all extraneous substances—to equalise their quality—and to render them as nearly parallel as possible. To bear these objects distinctly in memory, will serve greatly to facilitate the comprehension of the machines about to be described. Messrs. Hibbert and Platt, who are the most extensive manufacturers of cotton machinery in this country, have produced a series of engines for the treatment of cotton from its raw state upwards, which have never been equalled in beauty or perfection of workmanship. These were exhibited by them in Hyde Park in 1851; and as they represent the most finished productions of mechanical art in this branch of industry, we shall briefly describe them from first to last. The cut below repre-

sents a convenient form of cotton gin, now much employed in cotton spinning districts, for the preparatory cleansing of this substance.

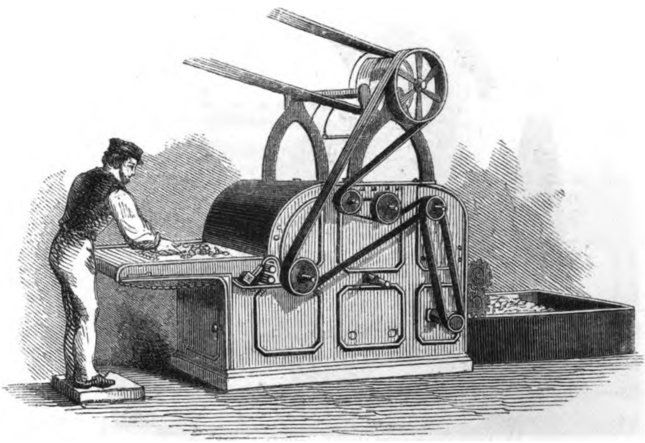
The first of the machines used in the preparation of cotton is the opening or cotton-cleaning machine. The cotton is drawn into it by being placed on an endless apron, which presents the material to two rollers armed with coarse teeth. These seize the cotton and draw the locks apart, and then pass them on to other



rollers with finer teeth. By these the fibres are still further opened and straightened, while the dirt and other foreign matters are thrown out at the bottom, the partially purified cotton being passed on to the extremity of the machine. One of these machines is capable, with the expenditure of about one-horse power, of cleaning three thousand pounds of cotton in a day;

and the revolution of its cylinders, in tearing open the material, is at the rate of 500 per minute.

The cotton is then taken to a second opening and scutching machine, shown in the cut; here it is again put on a moving endless apron, and introduced into the machine by being drawn between a pair of rollers, and delivered slowly out to meet the blows of the "beater," which revolves with great rapidity, and drives all the heavy particles of dirt, sand, &c., down through a grating, which, however, is too fine to allow the flakes of cotton

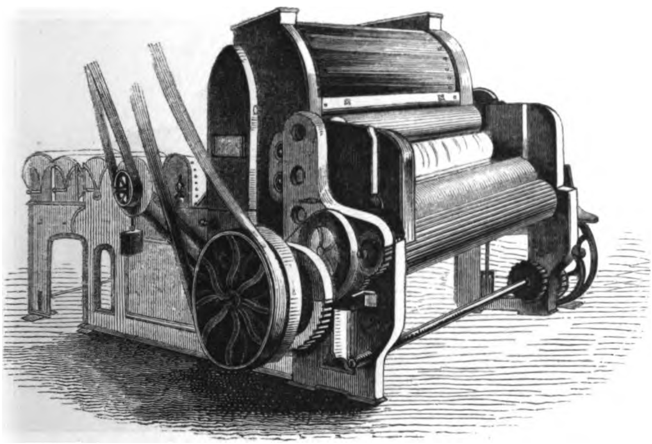


OPENING MACHINE.

to pass through. These are carried through to an iron roller, round which they are led; and as the roller is kept revolving, they are wound on it so as to form a continuous sheet of loose fleecy texture, called a "lap." This roller is so arranged, upon a peculiar principle, as to compress the lap as it is wound upon it, thus enabling the roller to hold much more than it otherwise would. These rollers are called "patent consolidating calender rollers." This lap is then transferred to the first, or breaker-carding machine, and the end of the lap last

wound on the roller is led in between two feeding rollers, and carried by them into contact with the cards of the machine, which draw out and straighten the fibres of the cotton.

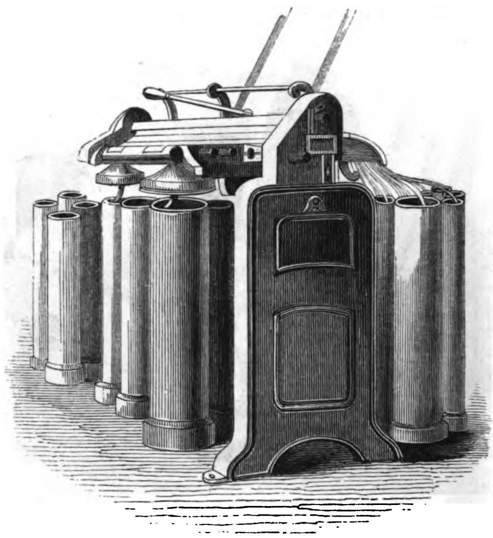
The large cylinder of the carding machine, shown in the cut, on which the cards are fixed, is made of iron, and is turned perfectly true. The cards are fastened to it by nails driven into small wooden plugs, inserted at intervals in the circumference of the iron cylinders; and the patent bracket slides for carrying the smaller



CARDING MACHINE.

rollers are remarkable for the simplicity and solidity of their construction. After passing over the surfaces of the card-rollers, the cotton is stripped off the last roller, called a "doffer," by means of a steel comb or doffing plate, mounted on an iron stock, the whole width of the doffer, which rises and falls with a sort of chopping motion, and at each fall catches a number of the fibres, and, disengaging them from the wires of the cards, forms them into a loose, open, broad film of cotton, called a "sliver." The end of this is narrowed, and led into a

conical aperture about an inch in diameter, in the top of the coiler. Inside the coiler is placed a pair of rollers, which take the end of the sliver first presented, and continue to draw it through the conical hole, and deliver it into a deep can placed below the rollers until it is full, when the end is broken off. In general, the cylinders of the carding engines are made of wood, but in the machines in question iron cylinders are used, which have the advantage of greater durability and



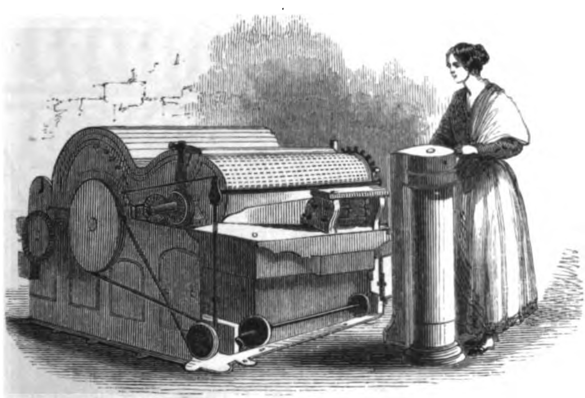
LAP MACHINE.

permanence of shape under all temperatures. The machinery for feeding the engine is also capable of a beautiful adjustment to the length of fibres of the cotton —or "staple," as it is technically called.

The can is then taken to the next machine, called a "lap machine," shown in the cut, and is there placed alongside numerous similar cans; and the ends last broken are led one by one out of each can, and introduced

between a pair of rollers, which draw all the several slivers at one time into the machine, and coil them side by side on a small iron roller, so as to make them into a lap—that is, a long sheet formed of the slivers which adhere to one another in some degree.

This lap is now transferred to the second or finishing carder, shown in the cut, and is still further carded, doffed, and coiled in the cans, as previously described. The lap, which, when it enters the machine, is formed of thirty or forty single slivers, is carded down in sub-

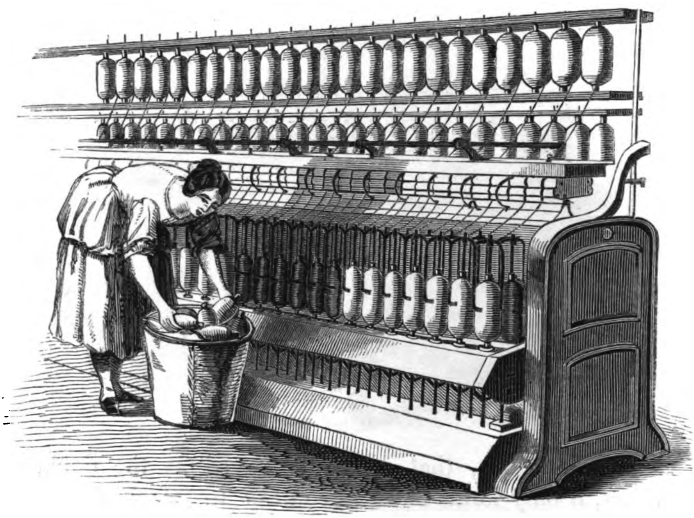


FINISHING CARDER.

stance so much, that, when taken off at the doffing roller, it only forms one sliver out of the whole number that entered, and thus the effect of any irregularity that may exist in any one sliver is entirely lost in that which is composed of so many various ones. The cans from the finishing carding engine are now taken to the drawing frame, and the slivers are first passed through a pair of rollers travelling at a slow speed, and are then seized by the next pair, which run faster, and therefore draw away the cotton at a greater rate than it is furnished to them by the first pair. This has the effect of making

the sliver longer and thinner, and at the same time straightens the fibres; and it is still more drawn by a third, and even a fourth or fifth pair of rollers, travelling faster than the middle pair, so that the slivers are very much attenuated by this process. Three of these slivers are led into one conical hole in the coiler, and the cans, revolving as before described, coil the sliver inside them.

As yet the cotton fibre has received no twist; the object has been, as before mentioned, to equalise, clean, and straighten it as far as possible And this has been

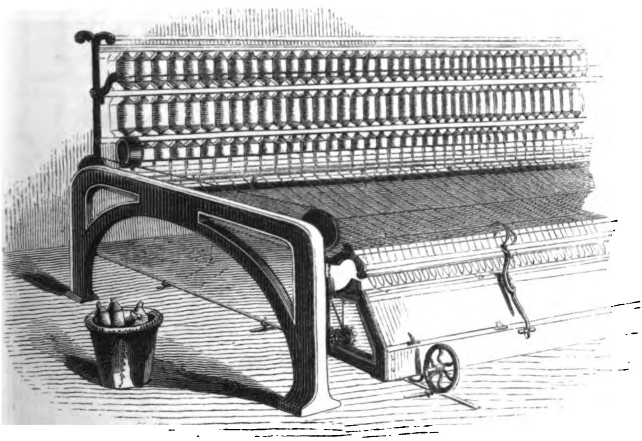


ROVING FRAME.

admirably accomplished, as may be readily seen by examining the material as it proceeds from the last-named machine. It now offers the most remarkable contrast to its former state as it came from the bale. It is of a pure white colour, of a soft fleecy texture, and its delicate filaments lie as nearly parallel with each other as possible. It is in every respect in a very different

state from the tangled, harsh, and dirty locks which were first presented to the operations of the scutching machine.

The cans containing the slivers from the drawing-frame are taken to the slubbing-frame, where the slivers are to receive a slight degree of twist. Previously to this, however, they are led out of the cans, and passed through three lines of drawing rollers, to reduce the size of the sliver, and to straighten the fibres still more. After passing these drawing rollers, they pass down to the "flyers," which in these machines are of an improved



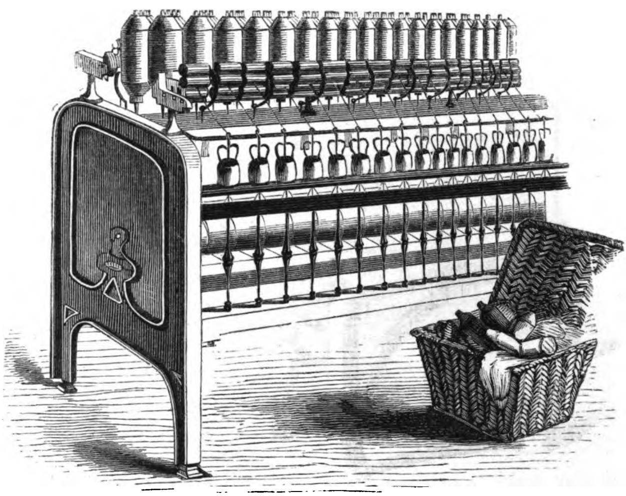
SELF-ACTING MULE.

construction; the spindles having two inches more bearing, and the flyer having a one-inch shorter leg—an advantage that enables the manufacturer to run the spindles one-fifth faster than by the usual construction.

The flyers give a certain amount of twist to the "slubbing;" and it is by them wound on bobbins, which are then transferred to the second or intermediate slubbing frame. Here the cotton undergoes a process similar to, but finer than, that of the first slubbing-frame. The

roving-frame, shown on page 128, comes next, and the bobbins from the second slubbing-frame are placed in it; the slubbings are here reduced by the drawing-rollers still finer; they are then twisted still more by the flyers; and lastly they are again wound on bobbins.

The "mule" is the machine next in order, and a beautiful and complex engine it is. Here the bobbins, taken from the roving frame, are again passed



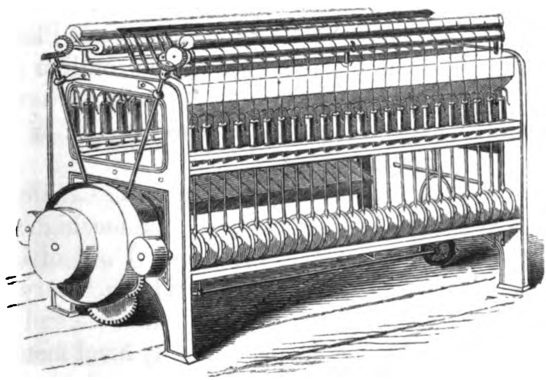
COMMON THROSTLE.

through three lines of smaller drawing rollers, and then delivered on to the points of the spindles, which, by their rapid revolution at the time the carriage is drawn out, twist the roving into yarn. On the return of the carriage, the twisting operation ceases for a time, and the newly spun yarn is wound on to the spindles in the well-known form of "cops."

The other form of machine employed for twisting cotton-yarn is called the throstle. It consists essentially

of sets of drawing rollers, which regulate the supply of the yarn, and of a series of vertical spindles with bobbins. The latter revolve at a very rapid rate, and both twist and wind up the yarn. The noise produced by their revolution, which is a loud singing or rather humming sound, has given the machine its peculiar name.

By this machine, or by the mule, the yarn is at length produced which is fit for textile purposes. The product of the mule is of a finer quality than that of the throstle,



IMPROVED THROSTLE.

and the varieties thus produced are applicable respectively to the coarser and finer fabrics.

Among the improvements in the machines now employed in the cotton manufacture are a number of ingenious mechanical arrangements of a minor kind, which regulate either the quality or the uniformity of the cotton-yarn, or which serve to control, direct, or arrest the operation of the machines when in action. In some of these the breaking of a single delicate thread is sufficient immediately to stop a ponderous machine, with perhaps a hundred or two hundred spindles in full revolution. At the Great Exhibition many of these improvements

were shown: but it is difficult to obtain either a clear idea of their precise nature, or of the method by which the effects are produced, from any verbal description, however clear it may be. The cut, however, shows a very excellent form of throstle, in which the spindles are driven by friction wheels. The machine of M. Risler, a French manufacturer, called by him an Epurator or Purifier, has been recently introduced for the purpose of better cleaning the cotton in its first stages. It was rewarded at the Great Exhibition with the Council Medal. In all essential respects, the sketch above given of the machines made by Messrs. Hibbert and Platt, for this particular manufacture, conveys an outline of its principal features; and these remain unaltered, however varied the aspect of the machines made in this or other countries may appear.

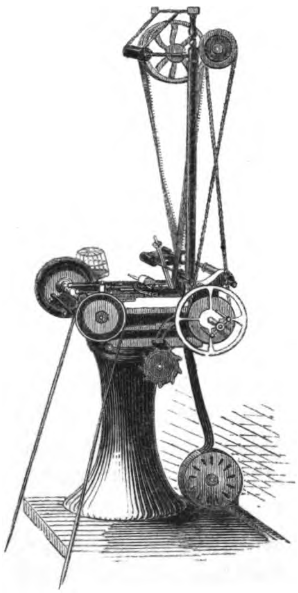
The quality of the yarn produced is designated by numbers attached to different edges, and the higher the number the more delicate is the yarn. Until of late it has been supposed that the beautiful machinery just described was incapable of producing the fine and delicate yarn which the Indian spinners by hand manufacture. About half-a-century ago, Sir Joseph Banks wrote of some yarn, then sent over to this country from the East Indies, that a single grain of it measured 29 yards, or at the rate of upwards of 115 miles to the pound! More recently, Indian yarn was sent to the Great Exhibition, of which forty-three yards would only weigh one grain. There has, however, been a great effort made by the English manufacturers to surpass their Hindoo competitors; and such has been their success in this respect, that cotton-yarn has been produced in this country nearly ten times finer than the Indian—or in other words, the Indian yarn was ten times coarser than the British. The fineness of the cotton-yarn is denoted by the number of hanks, of 840 yards each,

contained in one pound weight of 7,000 grains. Therefore the following statement will render it evident to the reader, that of the fine kinds of yarn alluded to, that number of hanks or skeins, of 840 yards each, was contained in one pound, which is indicated by the numeral affixed. Specimens of British yarn, not higher in number than 350's, were spun in one factory only prior to 1840, that of Messrs. Houldsworth; and for ten years subsequently, 450's appeared to be the utmost extent to which the spinner could go. But, in 1851, surprising efforts to produce finer yarn were made, and with complete success. Yarn was shown at the Great Exhibition so fine, that the fibres of the cotton could only be discovered in the fabric by the aid of a microscope, and so intangible that it fell to pieces by handling! Yarn of 600's quality was shown, made into muslin and net, by Messrs. Houldsworth. Some French manufacturers, Messrs. Vautroyen and Mallet of Lille, also exhibited a specimen of 600's manufactured into muslin and net. Mr. Bazley, however, produced yarn of the extraordinary quality of 2070's, and Messrs. Houldsworth sent some as fine as 2150's. Yarn so fine as this is, however, quite unfit for weaving; and its extraordinary tenuity may be conceived when it is stated that a single pound weight of it would reach 1,026 miles!

The machine employed for producing the cards used in the cotton manufacture is one of such beautiful and ingenious construction, and is so intimately connected with the cotton machinery, that it may be very properly mentioned in this place. It is shown in the cut.

The cloth or web on which the card wires are to be fastened is led gradually, endways, through the machine, and, as it proceeds, is regularly punctured with a pair of holes, one after the other, to receive the wires. There is a coil of fine wire mounted on a reel, and this is gradually drawn into the machine, and a certain length,

rather less than an inch, is cut off, and bent into the shape of the letter U; it then receives a second bend, at right angles to the first, and is finally inserted into the two small holes previously made in the cloth. By the peculiar and beautiful arrangements of the machine, the two next holes are punctured in the cloth by the sides of the previous, and another U-shaped wire is cut, bent, and inserted; and this operation is repeated until the whole breadth of the cloth has been filled, when the material is moved endways, sufficiently to allow another row to commence; and this time the cloth is moved sideways in the opposite direction to that in which it was moved last, and so on, until the whole length of the cloth is complete.



When the machine is moved slowly round by hand, the operations of the various moving parts may be clearly traced, and the admirable mechanical combinations appreciated; but when it is made quite automatic, and is moving at full speed, the eye is scarcely able to follow the action so as to discern all that goes on.

Another ingenious and automatic engine connected with cotton manufacture was shown at the Great Exhibition by Mr. Coats. It is intended for the manufacture of bobbins by machinery. So large a number of bobbins is used for winding cotton-yarn upon, that it is of importance to produce them as rapidly and as economically

as possible, and these objects seem to be well accomplished by this machine.

The wood blanks, to be formed into bobbins, are roughed out in a previous machine into the shape of short plain cylinders, and these are dropped into a small hopper, which is placed above the centre of the machine. They are then, one by one, lowered by self-acting apparatus on to the centres of the lathe, which close up towards each other, and chuck the blank, when the cutter, appropriately shaped, moves towards it, and perfects the part between the two ends. A pair of cutters then finish the extreme ends, and lastly, the centres recede from one another, and the finished bobbin falls, making way for another blank to be operated on.

The manufacturing machines employed for the other textile substances—wool, flax and silk—are in many respects similar in their essential features of construction to those now described, but are varied in order to adapt them to the nature of the material upon which they operate. Those employed in the manufacture of woollen yarn we shall now shortly describe. The wool is generally sorted into various qualities before being submitted to any manufacturing machine. This having been done, its mechanical treatment commences. One of the most remarkable and ingenious machines in this manufacture was shown for the first time at the Great Exhibition by Mr. Douisthorpe; it was called a "woolcombing machine," and may be thus described:—

It is adapted for long wool. The wool is fed in by one pair of rollers on one side of the machine, and another pair at right angles to them on another side. At each of these places there is a pair of what may be termed shear-blades, not sufficiently sharp to cut the wool, but merely to nip a certain quantity of it, and draw it off with them, as they move away from the feed-

ing rollers, some three or four inches. In the next place, an upright metal comb is moved up so as to insert its points into that part of the wool which projects out from the point of the blades; and as soon as it has caught the wool, the blades recede from one another, and leave the wool sticking on the points of the comb, which then moves away from the shears, and carries the front end of the lock of wool over towards and above the circular metal comb, the teeth of which are upright. A brush formed to suit the circle of the comb is placed about three inches above both, and descends so as to bring the wool into contact with the teeth of the circular comb, and holds it there for a moment, whilst the straight comb, which brought it from the shears, withdraws itself from the wool, and leaves it to be carried round from about a quarter to a half of a circle, as the case may be; the long fibres of wool projecting out some distance, and coming in contact with a pair of grooved horizontal rollers constantly revolving. These rollers seize the long fibres only, and draw them out of the comb-teeth. They then pass through a bell-mouthed tube, and are drawn by two or three pairs of rollers, and passed on to a wooden roller, on which the long wool is wound. This last roller is made to travel end-ways in each direction alternately, so as to distribute the wool equally over it. The short wool, or "noyl," which remained on the teeth of the circular comb, passes about a quarter of a revolution with it, and then meets with a thin sheet of iron, the edge of which is inclined upwards to the direction in which it is moving, and lifts it gradually off the comb, when it falls down by the side of the machine, and is afterwards used for any purposes to which short wool is applicable.

This machine was one of extraordinary ingenuity and rare promise. It received the highest award of the Jury, in the Council Medal. It was very jealously watched,

and its working parts were generally, as far as possible, concealed from public inspection.

No machine, however, can entirely supersede the work of the wool-sorter, whose educated refinement of touch is necessary, in order to distinguish accurately the various qualities of the wool. The machine in question is not intended nor calculated to effect this; it is merely fitted for separating the short wool from the longer kind, and this it accomplishes with great facility and expedition. Other woolcombing machines have been invented, and are used in different places. Very generally, however, woolcombing is performed by hand.

After leaving these machines in the form of slivers, the wool is placed upon a machine called a "drawing-frame," the object of which is to equalise the size of the slivers. This machine consists simply of a feeding-apron, which presents the slivers to the drawing-rollers, and these deliver them into upright cases, as in the manufacture of cotton-yarn. The wool is then spun into thread by the mule, which is essentially similar to the same engine as used for cotton.

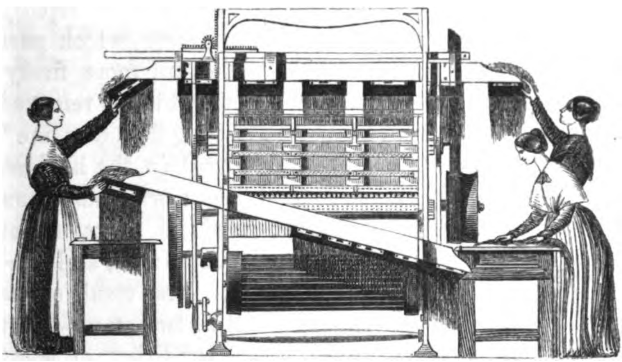
The short-wool manufacture requires some modification of mechanical treatment. This term includes the manufacture of cloth, while the long-wool manufacture relates only to that of worsted yarn. So far as the short-wool manufacture proceeds, in its preparation of the fibre into the form of a cord, we shall now advert to it. The wool after being washed, cleaned, and often dyed, is submitted to mechanical treatment in a species of winnowing machine, called a "willy." This machine, seizing the wool supplied to it from an endless apron, whirls it round within a strong case armed with iron spikes, and throws it out at the other end, purified from the dirt and other foreign substances which it contained. After this process it is mixed with a quantity of oil, which softens the fibres, and it is then submitted to the carding-engine.

In some of the modern wool-carding machines, the arrangement of the working parts is somewhat different from those of the ordinary carding-engine as used for cotton; but essentially the machines are similar. Mr. Mason of Rochdale has produced a very perfect set of wool carding engines, which were exhibited in 1851. The first carding engine, or scribbler, is a machine very like the cotton carding engine already described. It is supplied with wool by an endless apron, marked in lengths, and on each length is spread a certain amount of wool, so as to keep the supply regular. The wool is then caught by the coarse teeth of a roller covered with card wires, and is drawn into the machine. Here it is carded by a series of rollers of different sizes, and moving at different velocities. At the other end it meets with the taking-off or doffing roller, from which it is removed by the doffer-comb or blade, and is then drawn by rollers into a bell-mouthed revolving pipe, at one end of the doffer-roller. From hence the carded wool is led on to a small lap-machine, where it is coiled up on a tin hoop, and traversed alternately sideways in each direction, so as to make the coil regular; and when it is complete, a little bell rings to call the attention of the workman. From this machine the wool is taken to another carding engine, called a "condenser." Here it is carded again, and as it leaves the engine it receives a slight twist, and is coiled up in long bobbins or spools, which are then taken to the mule and spun. The subsequent stages of the short-wool manufacture are not essentially different from cotton spinning, as far as relates to the production of the yarn.

The mechanical treatment of flax next requires our notice. It is in many respects essentially distinct from that of cotton and wool, requiring in its early stages an entirely peculiar preparation. The textile fibre is obtained from the inner bark of the flax plant, and before

it can be got in a state in which it is capable of being spun, it has to be submitted to a series of mechanical operations, the object of which is to remove all extraneous substances, and to separate the filaments in a clean and uniform condition.

The first machine employed in this manufacture is the flax-breaking engine. This machine consists generally of a series of grooved rollers placed in very close contact, The flax is presented to this engine, and is seized by the rollers, and compelled to pass between them. In so



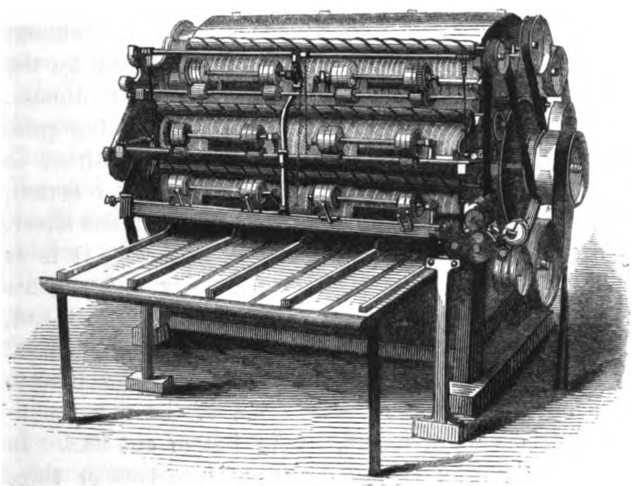
doing, the fibres are sufficiently broken to fit them for the next process, without being cut. The bruised flax is then taken to the next machine, which is called the scutching machine. In one of the most modern forms of this engine, the construction is as follows. It consists of a large disc or wheel of iron, placed vertically. On one side are attached brushes of steel wire, and on the other wooden blades. The flax is first presented to the side armed with blades, and the wheel being in rapid revolution strikes it, and removes a large part of the woody material, leaving the fibre behind. The flax is then presented to the brushes, and the action of these completes the process of scutching.

The machine next in order is the heckling-engine. One of the most modern of these engines is shown in the cut. The flax is taken to a table, and a small quantity of it, called a "strick," is laid with one end firmly secured in what is called a holder, made in some instances of gutta-percha, but more commonly of wood. It consists of two portions, which, like a mechanical hand, firmly grasp or hold the flax. These holders are then taken to the machine for heckling the flax, and are secured in a trough which rises and falls, and presents the holders, with their contained fibre, to the action of rapidly revolving cylinders, armed with iron teeth, which pass between its fibres, and divide them still more finely, separating also the short fibre or tow, which is removed to the bottom of the machine. The long flax, or "line" as it is technically called, is left behind in the holders. This process is repeated several times with machines having finer heckles or combs, until its fibres are at length reduced to a state of great smoothness, and present a soft and glossy appearance. The result of the heckling process is to leave the flax in two states—that of long smooth fibres, called "line," and that of short and coarser fibres, called "tow."

The treatment of the short flax or "tow" differs from that of the "line." In illustration of the machinery used for this process, a beautiful set of engines was arranged by Messrs. Lawson of Leeds, in the Great Exhibition, and we shall here briefly describe their arrangements. The tow is first submitted to the carding-engine, shown in the cut. Here it is passed round the carding-cylinders, and is taken off by three separate doffers, as in the cotton process. These are, however, ingeniously arranged at different distances, apart from the main carding cylinder, so as to take off three separate qualities of tow. These three kinds of tow are then led off in the form of slivers to the side of the machine; here

they are combined together into one sliver, which is passed into a can ready for the next machine.

This is called a spiral gill drawing frame, and the sliver enters through guides, and passes through a pair of rollers called holding rollers. These travel at a slow speed, and deliver the sliver to the gills, which are lifted vertically, so that their fine points enter the fibres without disturbing them; and they are then traversed along by a spiral at each end of the bar, at a speed very



little faster than the holding rollers, so as to comb out and lengthen the sliver to some slight extent. The sliver is then seized by the drawing rollers, and these travel about six times as fast as the holding rollers, so that they would make the sliver six times as long as it was at first. It is then passed down through a doubling plate, which has slots in it at an angle of about forty-five degrees, to the direction in which the sliver is moving; and finally the delivery rollers take the sliver and deliver it into cans.

The roving frame is the next machine, and the action is much the same as that of the preceding one, except that, instead of passing into cans, the flax is here wound by flyers on to bobbins. The double tow spinning frame comes next. Here the tow roving passes through a plate to the holding rollers, and then over a friction plate to the drawing rollers, and finally is wound on to smaller bobbins. It is now ready for the reel, from which it goes to the winding frame, and finally to the loom.

The line, or long flax process, is somewhat different to that now described. The fibres of long flax are about ten inches in length, and have been reduced by the heckling to a state of great softness and smoothness. This state of the fibre renders preliminary carding quite unnecessary, and it is therefore merely submitted to a drawing frame, very similar to that used for cotton, by which the line is converted into a continuous sliver. By a series of processes, like those of cotton, it is at length brought into a state of great equality, and presents the appearance of a soft, smooth, shining riband, which is coiled into tall cans. The sliver thus equalised is then passed on to the roving and spinning machinery.

There is yet another modification of the flax manufacture deserving of notice. It is that of cut flax. In this case the flax is purposely cut into two or three lengths by a breaking machine. It is then heckled, and in other respects treated like long flax, in certain modifications of machinery, rendered necessary by the shortness of the fibres. There is a peculiarity in Messrs. Lawson's roving frame, to which attention should be directed. It has not hitherto been stated, that prior to communicating a twist to the sliver, it is generally passed through a trough containing water, which is commonly heated; the fibre is thus rendered more flexible, and capable of taking the twist better. In Messrs. Lawson's roving frame for cut flax the arrange-

ment is adapted for cold water spinning. The sliver passes through holding rollers and gills, and thence to the drawing rollers; and then it passes into a trough of water, to soften the gummy matter which holds the fibres together, in order to allow of a greater extension of the fibres than when dry. Afterwards it is passed over a cylinder heated by steam, in order to dry it again. It is then wound on to horizontal bobbins ready for spinning, but is in the form of a fine tape, called a sliver roving, or roving without twist. This is very different from the usual process, in which it is generally twisted before going to the spinning frame.

The next machine is the double spinning frame. Here the tape or sliver roving is passed over conducting rollers to a trough of cold water, then to the holding roller and drawing rollers, and thence to the vertical bobbins and flyers, where it is twisted and wound on to the bobbins in the usual way, ready for the reel and warping mill if going to the loom, or ready for the doubling frame if for sewing thread. The flax yarn produced on this latter system is of the finest description, and is woven generally by hand.

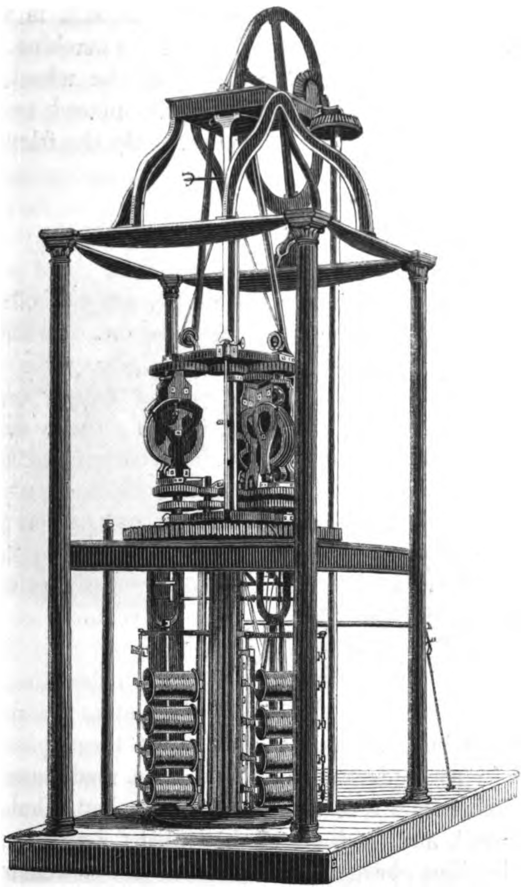
The production of large cords of flax, such as ropes and cables, can scarcely be omitted in our considerations of flax spinning and twisting. The ordinary arrangements of the rope-walk are, however, so familiar, that it is not necessary to advert to that part of our subject. A very interesting machine has, however, been recently introduced, and was occasionally shown in work at the Great Exhibition in the manufacture of ropes, of which the following description has been published:—The arrangement of it is such, that the rope is made within the compass of a small room, instead of requiring the usual adjunct of a long rope-walk. The small single yarns spun from the hemp are brought to this machine on bobbins about ten inches long, and

four inches in diameter; and forty-five of these are mounted in bearings in the moving frame of the machine, in three divisions of fifteen each, in such a manner that they revolve both around the centre of the machine, and horizontally in the plane of their axes, besides unwinding on their axes to give off the yarns. Fifteen of these pass up together, and are twisted into strands, there being three such strands, all independent, at the time they are being twisted—and the three being afterwards united at the upper part of the machine, and twisted in the reverse direction into one rope, which is then led over a pulley down to a winding reel near the bottom of the machine. The wheels giving the final twist to the strands, when forming them into rope, are encircled by a toothed wheel, geared both inside and out, and having an internal smoothly-turned flange of the same diameter as the pitch line, against which similar flanges on the planet wheels roll. This serves to steady them, and to keep them from flying off by their centrifugal force. This double-toothed ring is so geared to the revolving parts of the machine that, when it is fixed, the average amount of requisite twist is given to the strands; but it can be unlocked and put into motion by a pinion working into its outside edge, so as to give more or less twist according to the size of the pinion put on. There is also a provision for change of wheels below the floor of the machine, when more or less twist is desired in the rope itself.

This machine, shown in the cut in the next page, excited great attention, and was invented by a Mr. Crawhall of Newcastle-on-Tyne. It was rewarded by the jury.

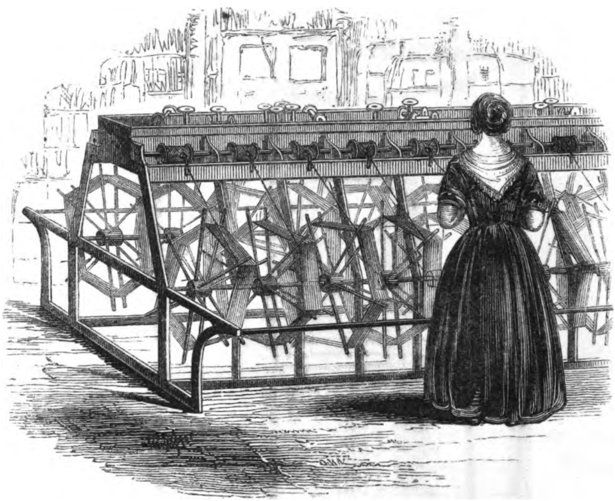
From the fact that Silk, the manufacture of which will now occupy our attention, is received into this country in a wound state, being a continuous fibre, it does not require to undergo the preliminary operations of carding and cleaning, but it is at once taken to the machines,

merely undergoing a slight washing or soaking first. The whole arrangement of the machinery used in the manufacture of silk will be readily understood by those



who have been able to master the general details of spinning machinery for other substances. And it will be seen to be as simple as possible. The first engine

in the series is the winding machine (see cut). In the most modern form of this machine, the silk, which is imported into England in skeins or hanks, is placed upon a light wheel intended to hold it, and deliver it off as it is wound. The bobbins on which the silk is to be wound are placed on the upper part of the machine. The silken fibre passes from the skein off the wheel, and is conducted between two glass pins placed perpendicularly, and set close to each other. By the friction of



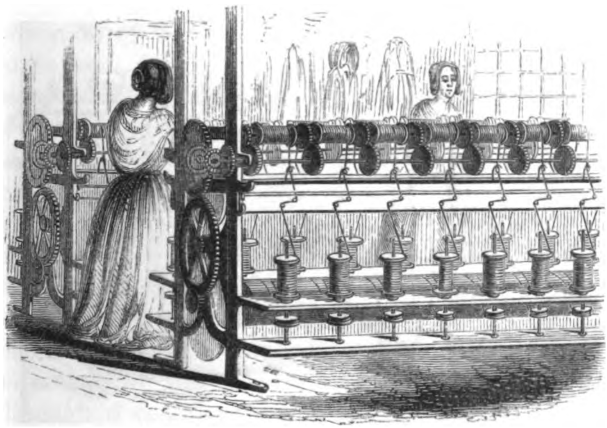
SILK-WINDING MACHINE.

the silk against the smooth surface of these pins, the fibre is in some degree smoothed, and made uniform. The bobbins then receive the silk, and when filled they are removed, and fresh ones substituted for them.

The bobbins charged with silk are now taken to the next machine. Hitherto the fibre has not received twist, and before it is ready for that it requires to be "cleaned." The next machine, which, however, has no analogue in any of the cotton machinery, is called the

cleaning machine. The bobbins of silk are placed upon this machine, and the silken fibre is caused to pass through a minute cleft in a piece of steel, which is called the cleaning plate or knife. In passing through this slit the fibre is rendered uniform, and all roughnesses are removed from its surface.

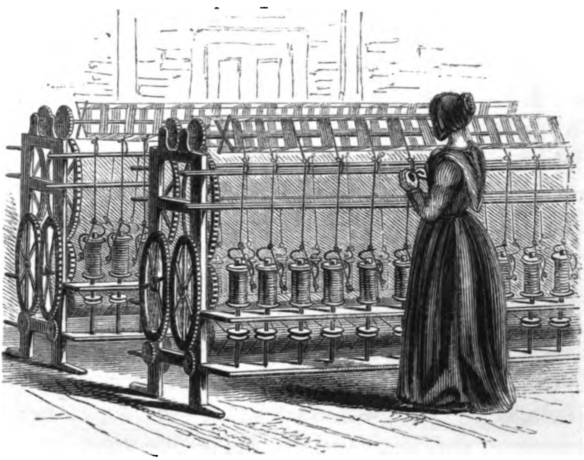
The fibre is now in a state in which it is prepared to receive the twist, and the bobbins from the last machine are now taken to the spinning machine. This engine is one of great simplicity. It consists essentially



SPINNING MACHINE.

merely of the bobbin and flyer used in cotton spinning, and of the machinery necessary for regulating the rotation of these bobbins, and the revolution of the delivering bobbins containing the untwisted silk. The machine is shown in the cut. The bobbins charged with silk are placed horizontally at the upper part of the machine, and the fibre is taken off from them, and passing through a loop is conducted down to the vertical spindles, and passing then through the flyer, is twisted and gradually wound upon the bobbins. The single thread of twisted silk is thus completed.

In order, however, to produce a stronger thread, the silk has to be taken to another machine, called a doubling-engine. But in reality more than two threads, and often as many as ten or twelve, or more, require to be "doubled," or laid together. In this machine the threads of silk are simply unwound off the bobbins and laid together side by side. The silk-throwing machine is, therefore, the next in the series, by which these parallel threads are twisted together (see cut). The



SILK-THROWING MACHINE.

expression silk-throwing is to be understood as simply referring to twisting the threads together into one cord. And the machine which accomplishes this is very similar to that employed for twisting the single thread. It is, however, furnished with the ingenious addition of a tell-tale or stop, which acts almost as if it were endowed with intelligence. If one of the threads accidentally breaks, a minute lever is acted on by the falling of the loop through which the broken thread passed, and by which it was kept up, and the bobbin which is connected with

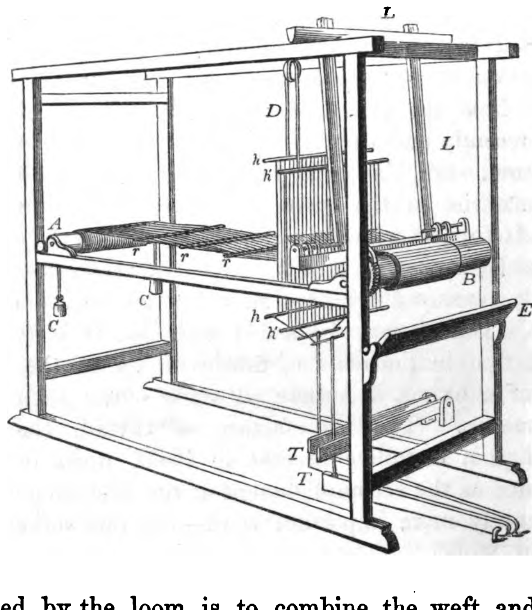
it is instantly stopped. By this means the attendant immediately discovers the accident, and after reuniting the thread, sets all in motion as before. Were it not for this ingenious provision, the silk would be liable to become extremely irregular in its texture, and unfit for manufacture into woven tissues. The very strong kinds of silk are twisted by hand, after the manner of ropes, machinery not being so applicable to the production of this kind of thread.

The next subject to which our attention is to be directed in the present chapter, is to a general consideration of that machinery which produces a woven fabric from the various textile substances which have been recently under notice. We have traced the progress of cotton, wool, flax, and silk, from their condition as raw material to the termination of their first stage of manufacture, in which they appear in the form of smooth and uniform threads. In this state they are respectively largely employed for an almost infinite variety of purposes. But it may be safely said, that it is to their production in the state of fabrics fit for all the varied uses of mankind, that these substances owe their chief importance. The manufacture of thread, therefore, although a complete process in itself, must only be regarded as the accomplishment of the first step in the immensely more important work—the production of a woven tissue.

The loom, in all its varieties and adaptations to the nature and quality of the material employed, is the great instrument by which this result is effected. And although simple in its essential principles, it has undergone such a series of additions and improvements, that it is, in many instances, as now employed in our great factories, a very complicated engine. Originally, however, the loom consisted of the fewest possible parts, and was a contrivance easily put up or removed at the pleasure

of the weaver. Before proceeding further, and in order to render any future descriptions intelligible, we shall here state the chief parts of an ordinary loom.

The annexed engraving will greatly assist in the comprehension of this machine. Those threads of a cloth which run the whole length of the piece are called collectively the warp. Those which pass across its width, from side to side, are called the weft. The object accom-



plished by the loom is to combine the weft and the warp together into one fabric, and this is effected by causing the thread of the weft to pass alternately above and below the longitudinal threads of the warp. Now the machinery by which this is effected may be thus arranged:—It consists first of an apparatus for stretching the warp. Secondly, of a contrivance for raising half the threads of the warp and depressing the other

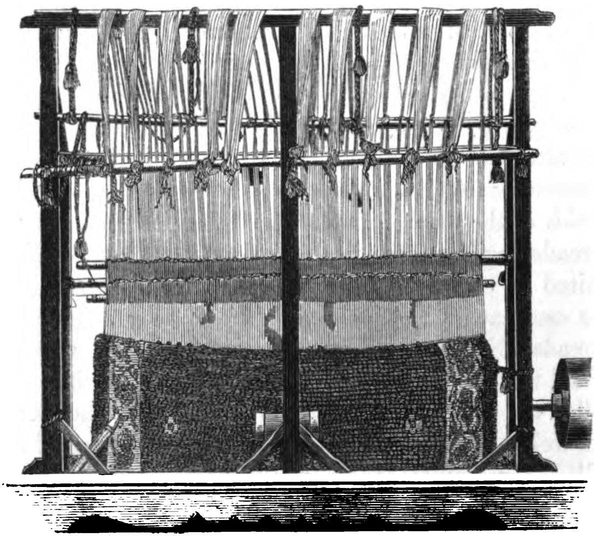
half, so as to open a space through which the weft passes. Thirdly, there is an instrument for casting the weft between the opened threads of the warp. And lastly, there is a contrivance for striking each weft thread close up to the one previously thrown.

The relative position of these parts may be best seen by the engraving: A is the beam on which the warp threads are wound, and at the other end is another beam, B, on which these threads when woven into the fabric are rolled up. In order to keep the warp tightly stretched, iron weights, C, are arranged so as to keep up a constant pull. In order to prevent the threads of the warp from entangling, flat rods, *r*, are placed horizontally between its alternate threads. The threads of the warp are alternately lifted and depressed by what are called the *healds* of the loom, *h;* these are looped strings, the warp threads passing through the loop. The two healds are united by a rope or pulley, D, so that the lowering of the one causes the elevation of the other. The warp threads also pass through the teeth of an instrument called the reed, which is secured to a swinging frame called the batten, L, because it beats home the weft to the web. At the bottom of this frame is a sort of shelf called the shuttle race, along which is thrown the shuttle. The shuttle is merely a boat-shaped piece of wood, containing in a hollow in the middle the bobbin of yarn which is to form the weft.*

These essential features of the loom being understood, it will be easy to comprehend the varieties to which they may be subjected, as these are influenced by the wants or the capabilities of the workman. The loom has been known for many centuries in India, in Egypt, and in other countries. And after its first discovery it seems to have undergone little or no improvement at the hands of the weavers. For the Hindoo

* Useful Arts and Manufactures.

looms of the present day are in all respects similar to those employed long before. The annexed engravings represent one or two kinds of loom employed in India, the originals of which were sent to the Great Exhibition of 1851. One of these is a carpet loom from Mysore. Another is a loom for making the celebrated Dacca muslins, and a third is the ordinary weaver's loom. That these rude instruments are

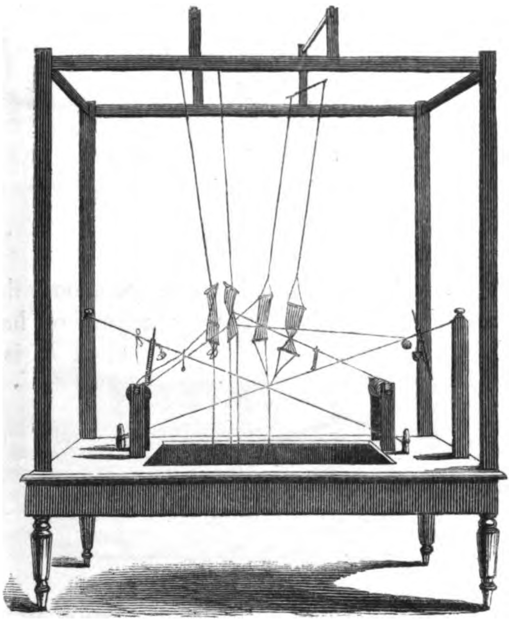


HINDOO CARPET LOOM.

capable of producing, through the extraordinary delicacy of manipulation of the weaver, the most delicate and beautiful tissues, will be understood when the statement of Tavernier is repeated. He says there is made in certain parts of India a muslin so fine, that when a man puts it on, his skin shall appear as plainly as if he had no covering upon it. And some of the rich Mohammedan Indians are said to have turbans of so fine a cloth, that twenty-five or thirty yards of it will only

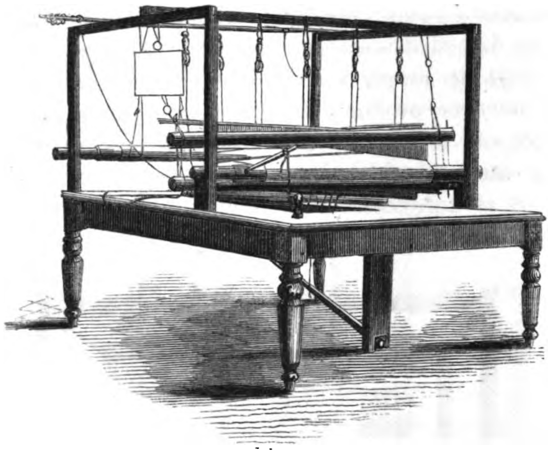
weigh four ounces; muslin is also said to be made by them so fine, that when laid on the grass, and wet with dew, it is no longer visible. Our own manufacturers have, however, produced finer fabrics than these.

Since our business lies more exclusively with the purely mechanical varieties and construction of the loom, it is unnecessary more minutely to pursue this



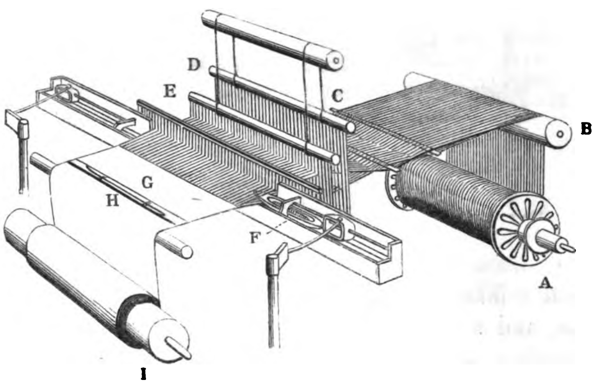
DACCA MUSLIN LOOM.

subject. The power-loom, which is an automatic engine, and which, for all the most important business of weaving, is now almost exclusively employed, is an extremely interesting machine; and the accompanying diagram illustrates in the clearest manner its most important parts. The warp is coiled up on the beam A, passes over a roller B, and is then carried through two



ORDINARY WEAVER'S LOOM (HINDOO).

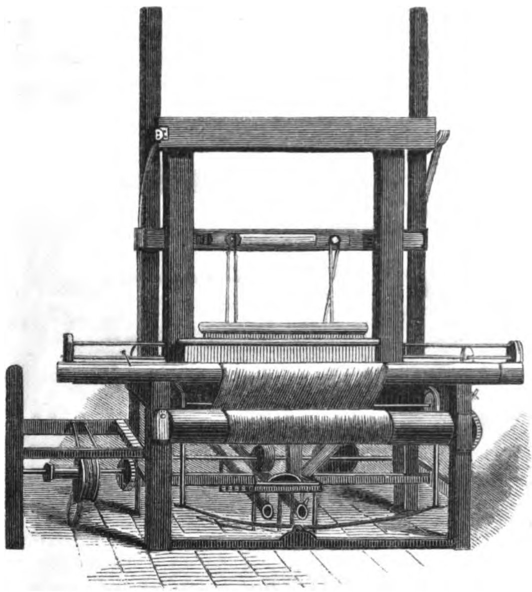
healds D, E, which form the interval (or shoot) through which the shuttle F is driven by a sort of hammer worked by a lever. The finished cloth G is kept



stretched by the temples H, and is wound up on the cloth-beam I. The action of this loom is as follows: it raises and depresses the alternate threads of the warp,

it throws the shuttle, it drives up each thread of weft with the batten, it unwinds the warp off the warp-beam, and it winds up the woven material upon the cloth-roller.

The original form of the power-loom is well shown in the cut, which is taken from a photograph by the

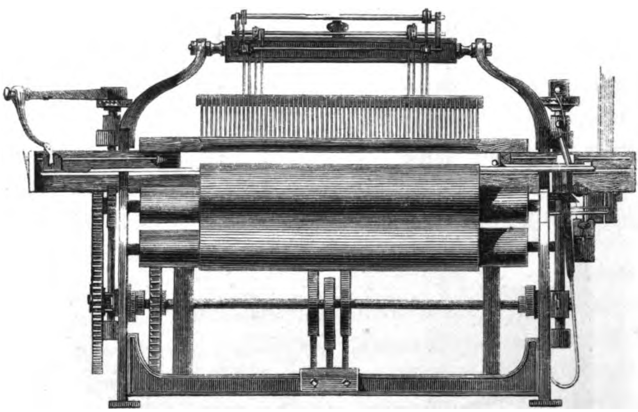


author, of one which was made half a century ago, and exhibited in 1851. When contrasted with the engraving below, which represents the modern power-loom, its cumbrous construction will be very apparent. This machine was appropriately placed by the side of one of the most modern engines, sent by Messrs. Kenworthy and Bullough. The latter was only about half the size of the cumbrous original machine, and was made chiefly

of iron, while the former was principally constructed of wood. This machine is shown in the cut.

By the best of the old power-looms, not more than one-third the amount of cloth can be produced as compared with the workings of the new looms, although twice the amount of labour is required to produce the same quantity in a given time.

An experienced operative will produce 26 pieces, 29 inches wide and 29 yards long, of printing cloth of *eleven* picks per quarter inch, from two such looms as those represented in the cut, in a factory working



sixty hours per week. The weaving of each piece costs 5½*d.* The same person, if set to work at one of the old looms, could only produce four similar pieces, each of which would cost 2*s.* 9*d.* for weaving alone; thus an immense saving is effected by the new looms for weaving alone. With such facts before us, it is not difficult to account for our vast superiority over all other nations of the globe in the production of every description of cotton fabrics.

An inspection of the engraving will show that the

power-loom is in fact a more complicated piece of mechanism than it appears to be. And this need not surprise us, when it is remembered that it fulfils all the duties of the weaver. It throws the shuttle, operates upon the healds, the batten and the beams, just as if an intelligence were communicated to it. But still more remarkably, this loom will not go without weft. On the old plan it was indifferent to the loom, so to speak, whether it had weft or not. Its operations were continuous, and the empty shuttle flew as before, but of course without making any cloth until the attendant stopped it and mended the thread, or placed a fresh bobbin in. But the loom of Messrs. Kenworthy and Bullough immediately stops under such circumstances. The moment the slender thread breaks, or is absent from its accustomed place, the noisy machinery is instantly arrested, the shuttle ceases to fly, and the wheels to move. The attendant then replaces the thread, and all goes on as before. By this ingenious and admirable contrivance the quality of the cloth is greatly improved, and much of the care and watchfulness of the weaver is rendered unnecessary, for the arrest of the machinery immediately informs him of the accident. So great has been the success of this invention that, it is said, the sale of licences under the patent right has produced to the patentees the large sum of 20,000*l.* In this loom also there is another remarkable improvement: the ordinary temples for stretching and keeping uniform the width of the cloth are dispensed with, and are replaced by a simple and self-acting mechanism, by which the cloth is kept distended at one uniform breadth, and the selvages are made uniform and good. Seventy thousand looms have been fitted with the self-acting stop, and upwards of one hundred thousand with the improvement just named,—a sure evidence of the value and utility of these contrivances.

Before the warp is brought to the power-loom, it has to be prepared by the unwinding of the threads off bobbins, and arranging them parallel to each other. In order to strengthen them, the threads of the warp have also to be sized or dressed with paste; both these operations are done by machinery, with a little assistance from the attendants. One of the most modern and improved engines for warping, as the first of these processes is called, is that form of warping mill invented by Hornby and Kenworthy. In this machine the warp threads are unwound from the bobbins, and wound on to the warp loom, or roller. There is a set of self-acting backing rollers, used to keep the threads tight when, from one being broken and requiring piecing, it is necessary to unwind them at all. The warp-beam is then taken to the next machine (called a tape machine, or warp-dressing machine), where the warp threads are unwound from off the beam, and passed through a reed into the size-trough, where they receive a dressing or coating of size or paste. They are then passed under a revolving brush, which removes the superfluous dressing; and afterwards they pass around two hollow cylinders heated by steam for the purpose of drying the threads; and lastly, they are wound on to beams or rollers similar to those on which they are placed at first entering the machine, and they are then ready for the loom. These machines were exhibited by the side of the beautiful power-loom at the Great Exhibition.

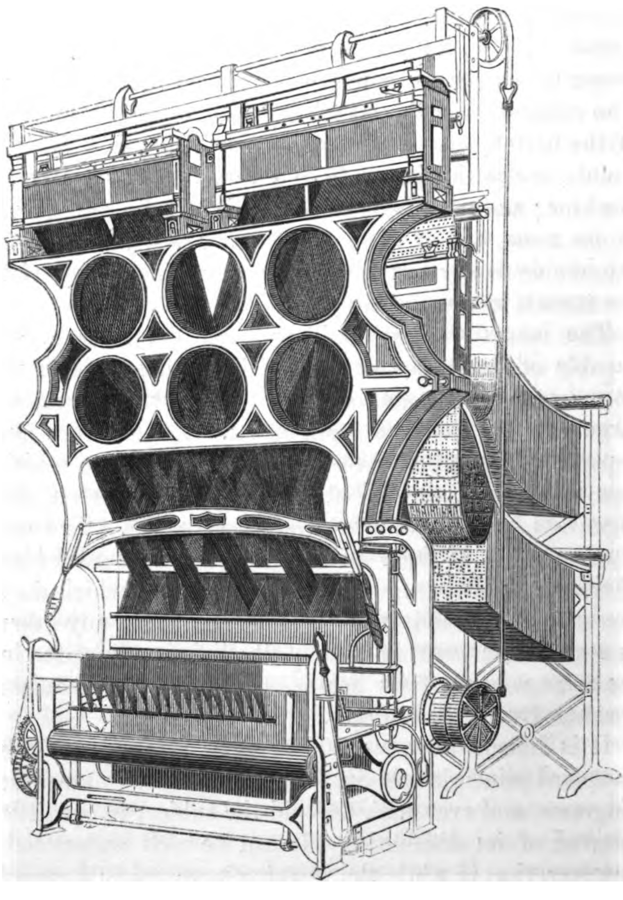
It must be evident that, since weaving is essentially the same whether the substance employed be cotton, wove flax, or silk, the general principles of construction adopted in any one power-loom are also to be found in others. But the nature of the fabric does in a certain degree require the modification of the general appearance of the loom which produces it. The looms which weave calico differ, for example, from those which pro-

duce sail-cloth, or the cloth employed for making the foundation for floor-cloths. The difference is, however, chiefly in their respective dimensions, and in the mechanical adjustments necessary to the altered circumstances of the case. The rate at which the best modern looms will go, is about 200 picks a minute. The larger looms are of course much slower in their action. The concussion of the machinery for driving the shuttle, of the batten, and of the alternately rising and falling healds, make the power-loom a very boisterous sort of machine; and when several hundreds of them are placed in one room, and at work at the same time, the din is intolerable to any but those whom long familiarity with the tumult has rendered unconscious of it.

The looms we have hitherto considered are only capable of producing an unfigured fabric, and have no power to form the embroidered tissues which form so large a part of domestic equipments. For this purpose, a peculiar apparatus is necessary, and looms to which this is attached are called Jacquard looms, after the ingenious Frenchman who first conceived it. The cut represents one of these looms, and will give a good idea of the extraordinary, complicated appearance which they present. Essentially this loom is similar to any other as regards the weaving part of it, differing however in the arrangement of its healds, and in the mechanism connected with them above.

It is difficult to convey a very clear conception of the Jacquard principle without the assistance of numerous diagrams, and even with this aid the subject is but little relieved of its difficulties. It can be well understood, however, that if while the weaving were going forward one or two of the threads of the warp were lifted or depressed while the others were undisturbed, the cloth then made would exhibit a different appearance in that part of it where these disturbed threads were, to the other

parts. It would show a certain mark on its surface; and if this disturbance were occasional, these marks would be repeated at a certain distance from one another, and thus



a sort of figure would be produced in the cloth. This is, in fact, what the Jacquard apparatus accomplishes, only in a methodical way. By means of certain cards with

holes in them, passing in succession over a square cylinder of wood also perforated with holes, and against which little pieces of wire are pushed at every revolution, which wires hold up the healds, the threads of the warp which pass through the healds are in succession lifted or not lifted, just as it may happen whether the holes in the card correspond with those in the cylinder or not. At every throw of the shuttle the cylinder revolves one fourth, taking up a fresh card from the long string of them connected with the loom, and the healds are lifted or not according to the position of the holes covered and uncovered. This goes on until all the cards have been used, and then the same series is again repeated. In this way a pattern is formed, the nature of which entirely depends on the arrangement of the holes in the cards, for upon that it depends whether one or another series of healds is lifted or not. The most laboured attempt at an explanation will probably scarcely prove successful; and if the above sentences do not furnish the reader with a glimpse of the true idea embodied in the Jacquard, it will be well for him to take an opportunity of carefully studying the machine itself.

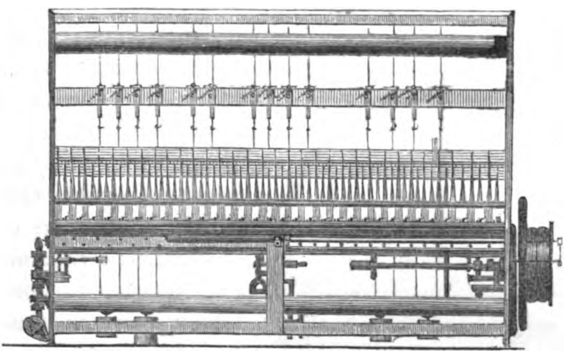
It might be supposed that no arrangement of this kind could produce any very delicate results, and that the patterns must be coarse and clumsy in their details. But to so great a nicety have machinists now brought this beautiful apparatus, and so accurately are the perforated cards arranged so as to fulfil their task of operating or ceasing to operate upon the healds, that the most delicate and beautiful designs are now accomplished by its means. Engravings have been copied with minute accuracy, and portraits have been embroidered with so much delicacy and vigour as almost to equal fine engravings on paper. At the Great Exhibition were shown by a French weaver, a portrait of the Pope,

another of the Duc d'Aumale, and another of the Queen of England, all produced by the Jacquard apparatus, and executed with artistic skill of a high order. There were also many other pictures, beautifully executed, and displaying in the most striking manner the wonderful resources of the Jacquard loom.

There have been many attempts to improve upon the principle of the Jacquard loom, and one of the most recent and successful is the invention of Mr. Barlow, which received the Council Medal at the Great Exhibition. In this loom, two perforated cylinders are used, and the cards are disposed on these in alternate order, so that while one cylinder is in action the other is changing its card and preparing for work. By this arrangement, the loom can be worked with a velocity 40 per cent. greater than that of the ordinary construction. The steadiness of its action is also greatly increased, and the strain upon the warp diminished. This improved mode of construction will doubtless be very useful in multiplying the product of the various looms now at work, and to which it might be adapted.

Various expedients have also been attempted for doing away with the perforated cards. In one of these, a cylinder like that of a barrel organ, and provided with pegs, which can be shifted to suit any required pattern, is substituted for the usual chain of cards. In another the pattern is painted on soft cloth, and this is employed in a kind of Jacquard frame to act instead of the cards. This, however, is only suitable for very coarse cloths. Among other inventions connected with the power-loom, exhibited in 1851, was an invention called the Shuttleless power loom, shown in the cut. It was adapted for weaving ribbons and fringes. The ordinary loom for weaving ribbons and other narrow fabrics requires, for the perfect play of the shuttle, a space three or four times greater than is

occupied by the web. In all looms hitherto constructed, the shuttle has been an indispensable necessity. To overcome this, and economise space, and, consequently, greatly to reduce the cost of production, has been the aim of the invention of Messrs. Reed, of Derby, the patentees of the loom. The principle is original, yet simple, and may introduce many improve ments in the art of weaving. The loom is filled with a fringe about 2½ inches wide, of which it produces 34 breadths at once, while the ordinary loom, with the same length of beam, could not produce more than 13

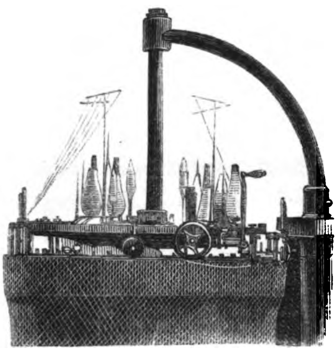


SHUTTLELESS LOOM.

or 14 breadths. Under the beam there runs a cam shaft, giving motion to the various parts of the loom. Attached to the breast beam there are levers or fingers that turn on a hinge horizontally; at the end of the fingers there is a small eye, or hole, through which the shute runs. As the warp opens to receive the shute, the finger moves and carries the thread across. At the same instant a needle rises and catches the loop of the returning thread, and holds it tight until the finger has returned and the batten advanced, when another change in the warp thread takes place; then the needle, which is flattened at the upper part and sharpened like the

blade of a knife, by a downward motion cuts the loop, and the fringe is complete. This process is repeated very rapidly, and is very interesting. In addition to the economy of space, it is clear, that where there are no shuttles there are no pirns or quills to fill, and no stoppage of machinery while the change of quill is being made. The silk, being wound on large bobbins behind the harness, is supplied with facility, and when the loom is once started, it need not stop until the warp is finished.

A still more remarkable and interesting loom is what has been called the circular loom, the head of which is shown in the cut. This loom, which is



adapted for weaving all kinds of looped fabrics, is made to produce the fabrics by means of a continuous circular motion. It may be worked either by hand or steam power. The great point of difference between this and the common stocking or knitting frame is, that the rows of loops are formed spirally, and not parallel to each other; the loops are also formed simultaneously upon different parts of the circumference of the frame. In consequence of these arrangements the goods produced are not liable to what is known in the trade as "running," arising from the defect or breaking of any one of the loops. The movement in the circular loom being continuous, and in one direction only, and not alternating forwards and backwards as in the ordinary loom, no time is lost in the back strokes, and in consequence a larger quantity of work can be performed in a

given amount of time. The amount of work which can be done by one of these machines is almost incredible. The one shown at the Great Exhibition by M. Claussen is provided with four "feeders;" it has 1,200 needles placed on the circumference, and will with ease make 80 revolutions in the minute. The quantity of loops or stitches made will be equal therefore to 1,200 multiplied by 80, equal to 96,000 per minute; and these produced by the hand-power of one workman alone. The machine can be made to produce, not merely knitted goods, in the ordinary sense of the word, but woollen cloths, as well as all kinds of looped fabrics.

The first idea relative to this machine originated about a century since in Falaise, a small village in Normandy, where at that period a considerable quantity of stockings and coarse knitted articles was produced. At a more recent period Mr. Brunel made several very important improvements in it, and came over to England for the purpose of bringing it before the notice of the manufacturers of this country; and it was this machine which first brought that celebrated engineer to England. It was patented in 1816, but, in consequence of its not being able to work with sufficient rapidity, it did not come into general use, and Mr. Brunel, occupied by other important duties, did not care to devote his time to perfecting it. A few years after its introduction into England, a Belgian, of the name of Touve, succeeded in constructing a common stocking frame upon the circular principle, which has continued in use to the present day. The improvement of the circular loom has continued, almost down to the present time, to occupy the attention of many ingenious persons—among others, we may mention M. Gellett, M. Jacquin, M. Fouguet, M. Bertollet—until finally it was brought to its present great perfection by the Chevalier Claussen. The principal improvements in the machine, as compared

with the original one, consist in placing the needles parallel to the shaft, and in the application of the common weaving reed to the circular frame.

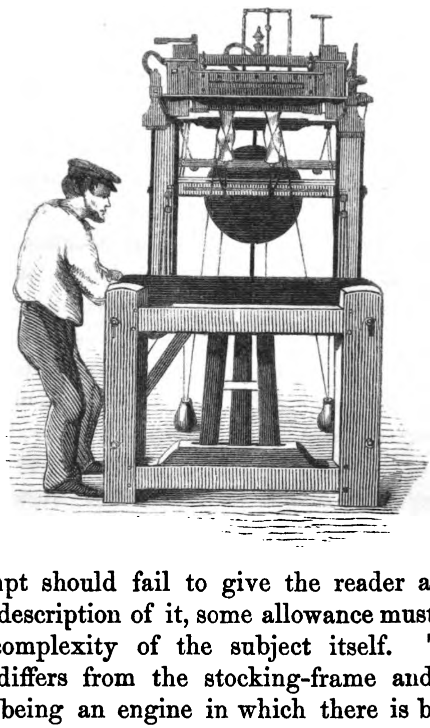
These machines are very extensively used in Nottingham. The number of "feeders" now at work is upwards of 6,000, each knitting from 4 lb to 6 lb. of yarn a-day. Some of the machines are so constructed that a girl 15 or 16 years of age is enabled with ease to work four feeders at a time; and the produce of her ordinary day's labour from such a frame is material sufficient for 20 dozen pairs of stockings. In addition to this large number known to be employed, many others, which are adaptations of the Chevalier Claussen's loom, are worked secretly in various parts of the town and neighbourhood of Nottingham. To the extended employment of these machines in Nottingham is mainly to be attributed the return to that town of the whole of the cheap stocking trade, which up to a very recent period, was entirely carried on in Saxony.

The cut on the preceding page is valuable and interesting, since it is copied from a photograph taken from the machine itself at the Exhibition.

The ordinary stocking frame, the ingenious invention of William Lee, is well known to most persons, and is represented in its best form in the accompanying engraving. The original of the cut given in the next page was exhibited in 1851. It will be understood that the stocking frame and circular looms, differ from the ordinary weaving principle, in the absence of the regular warp or weft. In the stocking frame, the fabric is composed entirely of loops, and of one continuous thread. This thread, by the assistance of a number of needles, is thrown into a succession of loops, which are connected with those previously formed, and which become themselves united with the next series. The hosier sits before his frame, and by drawing the thread from side to side, and acting

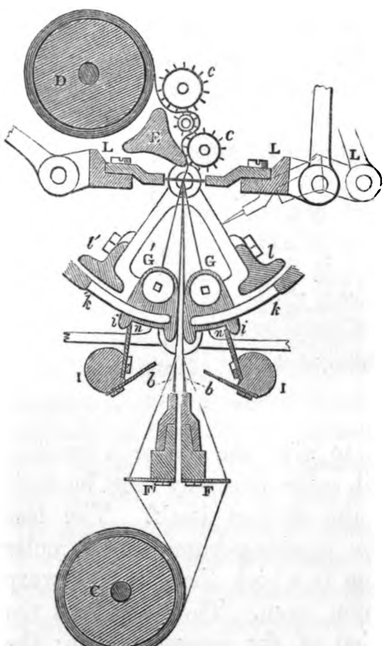
on the treddles of the frame with his feet, he sets the machine in action and produces his fabric.

The stocking frame appears to have been the parent of a still more beautiful and ingenious class of machines, namely, those employed in the manufacture of lace. The popular explanation of this machinery is more difficult than that of any which has preceded it, and if



our attempt should fail to give the reader a succinct and clear description of it, some allowance must be made for the complexity of the subject itself. The lace machine differs from the stocking-frame and circular loom, in being an engine in which there is both warp and weft, as in the common loom. The warp does not materially differ from that of the common loom; the chief peculiarity resides in the weft, and in the most curious and ingenious arrangement of the shuttle, called in this machine the bobbins. Supposing the straight

threads of the warp to be drawn out and placed upright, what would be necessary to make them into lace, would be to twist other threads diagonally around the warp threads, and by this means a mesh or network would be produced. This is what the machine we are about to describe really accomplishes. The warp threads are arranged on a long roller beneath, which extends the whole length of the machine, and before it is wound up on another roller above, the threads become entwined by hundreds of minute shuttles, with their contained weft; so that a complete network leaves the machine. The engraving represents very clearly the principle upon which this interesting effect depends, and shows the relative arrangement of the different leading features of the machine.



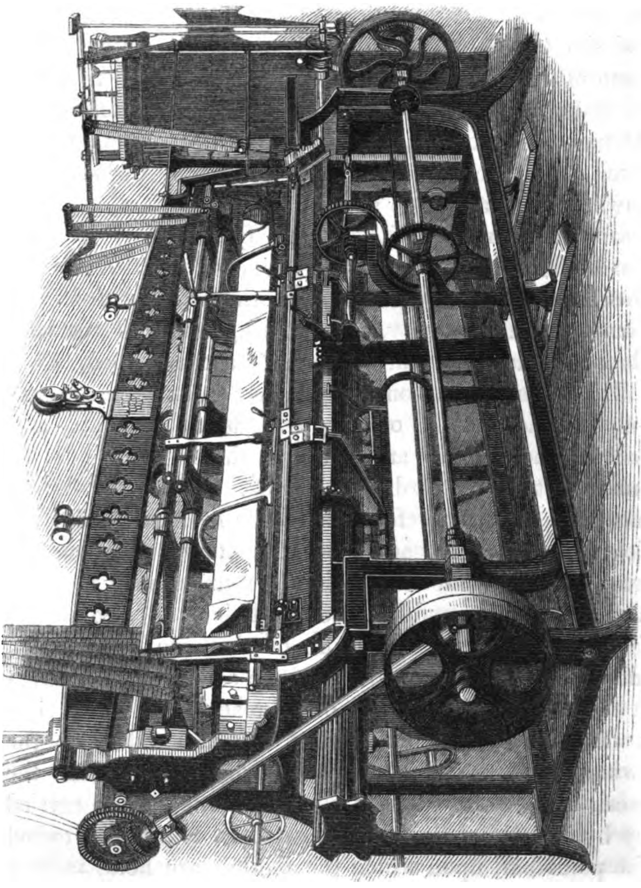
The shuttles, which are called the bobbins, differ from ordinary shuttles, in being formed of two thin brass discs fastened together, so as to form a very thin reel, in the hollow of which the weft thread is contained, as thread is wound on a common reel. Let us now trace the warp in its progress. The warp-roller, marked C, delivers its threads half on one side of a bar, called a guide-bar, F, and half on the other side of the opposite guide-bar F. The threads then pass upwards through

the eyes of a series of fine needles, *b b*, and then come in contact with the weft threads in the bobbins G G. These bobbins are capable of moving from side to side, passing between the threads of the warp; in this way the two bars, *l l*, alternately push the bobbins G G from one side to the other, and they are caught between the teeth of what is called, very appropriately, a comb, *k k*, on each side. In order to push the bobbins quite through, the rods, I I, are provided with tappets, which catch the under part of the bobbins and thrust them onward. By a motion given to the guide bars, F F, the warp threads move a little to and fro, laterally, so that the bobbin passes first on one side of the thread, and then back again on the other; in this way the first important result, namely, the twisting about of the weft threads around the warp threads, is accomplished.

But if the operation stopped here the machine would only produce a series of warp threads, all separate, and each twined round and round with the weft, just as one might wind a cord upon a stick. After the twisting has been done, therefore, the machine must make the bobbin carry its thread across the interval between the warp threads, and from twisting round one it must go across to twist round its fellow. This is effected in the following manner. The comb, of which we have spoken, moves at certain times from side to side, and as it moves it carries the bobbins from one thread to the other, thus a diagonal crossing is effected, and this, added to the twisting movement already described, completes the mesh or network. These interlacements are now carried up by a series of fine needles attached to a frame, called the point-bar, upon which the meshes are held, until a second point-bar brings up a fresh series. In this way the meshes are carried upwards, and the finished lace is wound upon the roller D.

The engraving represents a magnificent bobbin-net

machine, shown at the Great Exhibition, by Mr. Birkin, and although incapable of conveying a satisfactory view of the wondrous mechanism by which it operates, the



cut will at any rate give a general idea of its nature. At the further end of the machine is an apparatus on the Jacquard principle, which by a most ingenious arrange-

ment embroiders the lace as it is made. The beautiful machine, of which this cut is an accurate representation, was for some time permitted to work, and certainly constituted, to all who take pleasure in mechanical marvels, a most attractive spectacle. Its hundreds of bobbins passing alternately from side to side, formed not the least interesting of its parts.

When the lace has been finished by the machine, it is still in a state far from completion. It is covered with minute hairy filaments, the down of the cotton used in its production, and these require to be removed prior to its being fit for the market. At first sight this would seem impossible. It is however effected in a very simple and ingenious way.

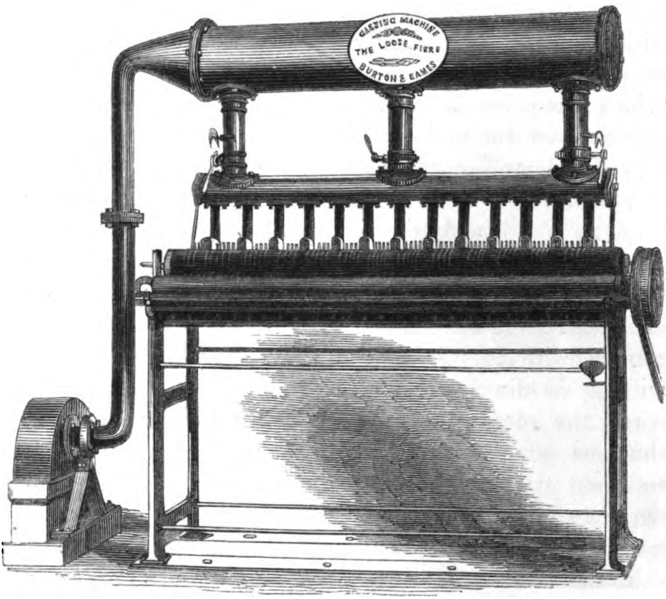
The method formerly adopted for removing these fibres from lace and other fine fabrics, was as follows:—An iron cylinder, the length of which was equal to the width of the lace or muslin, was made red-hot. The lace or muslin being stretched tight was then made to pass in contact with this red-hot iron, being pressed upon it with a certain force, and moved over it at a certain speed, the speed and pressure being so regulated that the lace remained in contact with the red-hot iron a sufficient time to burn off the superfluous fibres, but not a sufficient time to destroy or injure the delicate fabric itself.

If the velocity and pressure were allowed to exceed a certain limit, the fibres would be imperfectly removed, and if it fell short of that limit the lace itself would be damaged or destroyed. Experience showed the proper velocity and pressure for each description of fabric. The most delicate fabrics were thus made to pass, without injury, over the surface of a red-hot iron.

As the art of manufacturing gas was improved, and its application extended, it supplied an improved substitute for this purpose, of which the apparatus exhi-

bited by Messrs. Burton & Eames is an example. The cut represents this apparatus, as shown in 1851.

A row of gas-burners will be observed in the machine, the length of which corresponds with the width of the lace to be "gassed," as it is called. The lace is made to pass through this row of gas-flames with a certain velocity. It is possible to give to the lace a



velocity so great that the flame will not have time to destroy a single particle of the superfluous fibre; and, on the other hand, the velocity may be retarded, so as to destroy not only the fibre, but injure or destroy the lace. By experience, a certain speed is ascertained, which will give to the gas flames the time necessary to destroy the fibre without damaging the lace.

This, however, is only one of a great multitude of

contrivances of exquisite beauty and ingenuity which have contributed to render the fabrication of lace by machinery one of our most important manufactures. We here indicate the marvellous effect which these and like expedients have upon the cost of this article of female ornament and luxury. It is only twenty years since the labour expended in the fabrication of a *rack* of lace (a measure containing 240 meshes) cost 3*s*. 6*d*.; it now costs 1*d*. Prices have accordingly fallen in a proportionate degree. Formerly a twenty-four rack piece, five-quarters wide, fetched about 17*l*. wholesale price; the same piece is now sold for 7*s*. Such is the effect of science applied to the arts, in cheapening luxuries and extending their enjoyment from the wealthy to the humble.

After the lace has been gassed it is mended, and is finally washed and finished upon a machine called a lace-dressing machine. The dressing is usually carried on in a large room. Long iron frames, capable of being adjusted to any width by a screw, extend from end to end of these rooms. The lace is first dipped in a mixture of gum arabic and water, and is then wrung out and stretched upon the frame by means of pins or studs placed on the sides. The cut represents the arrangements by which the sides are moved away from each other, somewhat in the same manner as the modern telescope tables are made to expand. After the lace is thus stretched it is well rubbed with flannels, and then left to dry. The machine seen in the cut was exhibited by the maker in 1851, with the lace stretched upon it.

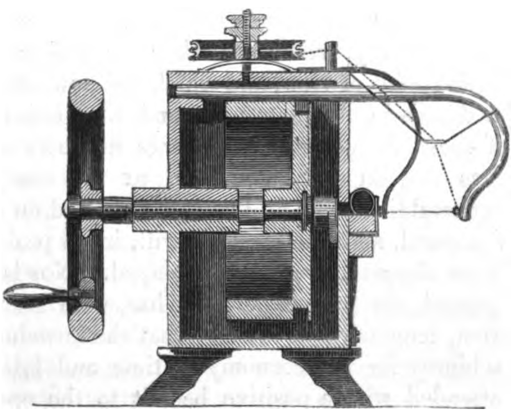
Upon such a survey of lace machinery as we have here taken, it may be confidently stated, that of all textile products it demands the highest degree of mechanical skill for its production. It has been aptly said of the bobbin-net lace engine, that in high mechanical talent it as far surpasses the best chronometers as they

surpass the common roasting-jack! And there is certainly a great degree of truth in this statement, for the movements performed by this machine approach more nearly to those of intelligence than probably any other form of machinery yet invented.

The problem of sewing by machinery, long considered of doubtful solution, has at length been satisfactorily determined, and there are at this moment some thousands of sewing machines at work in some of our manufacturing districts. There have been several machines recently introduced for accomplishing this seemingly difficult task, and they have been successful in their operation. At the Great Exhibition was displayed a sewing machine adapted for coarse cloth, invented by a M. Senechal. The thread is caught up by a curved point, moving eccentrically, and is then passed by it through the cloth. The stitches are then tightened, and the cloth is moved a little forward, when the same operations are repeated. The machine is automatic in most of its arrangements, and was exhibited at work sewing coarse canvass. Its highest speed was forty-five stitches in a minute.

Another, a much simpler and apparently more effective machine, is also the invention of a Frenchman. This machine is very small, and is worked with a treddle, at each stroke of which a needle passes up and down in a circular spring. The point of the needle passes through the fabric required to be stitched into a small hole, carrying the thread with it. The cloth is then shifted onwards and another stitch is formed. From two to three hundred stitches can be formed per minute, and that with surprising regularity and precision. The stitches are what are called chain-stitch. By shifting the fabric any stitch can be produced, and embroidery of all kinds effected. Recently an entire coat was made by this machine in half a day!

The Americans have also been actively concerned in perfecting this machine, and one called "Robinson's Back-stitch Sewing Machine," has been very successful. In this machine, which is capable of performing not only ordinary stitching, but also back-stitch, basting, whipping, and quilting, there is a combination of two needles, two thread guides, and a cloth frame. Each needle has a spring, to which pressure is applied in passing through the cloth, which spring holds the



thread. The whole of the movements are guided by a wheel with a handle, which a child can easily turn. A Mr. Wilson and a Mr. Money, also Americans, have each of them produced sewing-machines, capable of turning out excellent work with great rapidity.

At the Great Exhibition several sewing machines were shown. One of the most successful of these was the machine of Mr. Judkins, which is shown in the cut. This machine is very simple in its construction, and suited to sewing either a circle, curve, or straight

line, at the rate of 500 stitches per minute. But for a circle or curve the straight rack is removed, and one of a circular form applied to the side of the machine. This rack, in which the cloth is placed, is moved forward by means of a spring, at a given distance for every stitch. There are two threads employed, one of which is carried in the shuttle, and the other taken from a reel on the top of the machine, and passed through the cloth by the point of the needle, so that when it is withdrawn from the cloth both threads have been locked together, forming a firm and durable stitch. Subsequently to the Exhibition there has been formed a Lancashire Sewing Machine Company, which has taken the subject up in a commercial point of view, and which has now established regular dépôts in the metropolis and other cities for the sale of these useful engines. Large numbers of these machines are, in fact, now used at the ready-made clothing establishments.* They are also used for making ladies' apparel, and the machine will, in all probability, shortly be almost universally employed. Nor is this to be regretted, for past experience has, with scarcely an exception, demonstrated the fact, that the introduction of all machinery for the economy of time and labour has been attended with a positive benefit to the operatives whom, at first, it appeared to threaten with ruin.

The application of machinery to the production of woven and other fabrics has now been considered as far as our limits admit, and a connected view of this subject may now be taken, embracing the material in its raw state, following it in its stages of preparation, and finally observing it in its completed condition. In the department of industry thus surveyed, there is probably a larger number of persons concerned than in any other, and unquestionably there is a larger development of

* The price of one of these machines is about £30.

wonderful mechanical skill than in any other. Manchester and its vicinity forms the great field for cotton manufacturing industries; Leeds and the West Riding for the woollen cloth manufacture, and also for the flax manufacture; and Derby for the silk. These respective industries are, however, vigorously prosecuted in other parts of this country, and wherever circumstances combine to render a spot peculiarly eligible, as, by the abundance of coal, and of water, with a near source of the raw material, there one or other of them will certainly be found in full activity.

We have before explained our purpose of confining our illustrations of manufacturing machines chiefly to those which are either remarkable for their ingenuity or important in their connexion with our subject. In so doing it becomes necessary to pass by numerous mechanical contrivances of minor consequence to our matter, though ingenious and important in their respective businesses. We have, therefore, chiefly laboured to produce an accurate picture of the prominent features of a department of industrial activity of which our country has good reason to be proud.

We have traced cotton, from the pod to the thread, and onwards to the piece, and the other textile substances have been similarly treated. This might, therefore, seem the appropriate termination of the present chapter, but there is a class of machines remaining, intimately connected with the cotton manufacture, the beautiful arrangements of which justify our devoting a little space for their consideration. This is the calico printing machinery.

Calico, as it leaves the power-loom, is a fabric without any pattern, and of a dull light buff colour. In this state its uses are, of course, very limited. It is unfit for outer apparel, or for furniture, or in fact for any purpose for which an ornamental tissue is required. It is

also a hairy or downy tissue, and thus presents a coarse and unfinished appearance. The hairy filaments require to be removed, and the fabric must be made of a snowy white before it is likely to become of use to any large extent, either for apparel or for domestic ornament. The downy filaments are removed in the same manner as those of lace, either by rapidly drawing the material over a sheet of copper at a bright red heat, or by passing it through gas flames; and the bleaching is accomplished by an agency far more rapid than that of sunlight upon dewy meads, namely, by chemical force. The calico is boiled, washed, soaked in a solution of chloride of lime, then in weak acid, and so on alternately until, at length, all its impurities are removed, and it becomes as white as could be desired. Thus, in a few hours, by the combined assistance of chemical science and a few simple mechanical expedients, that process of bleaching is effected, which formerly occupied days and even weeks, and was then often imperfectly performed.

The bleached calico is now fit for the reception of its ornament, and this was formerly impressed upon its surface by means of engraved blocks, charged with colour, after the manner of paper-hanging makers. Now, however, very little block-printing of calicos is done; a more rapid and economical process has been discovered.

The patterns on printed calicos and similar figured cloths consist, as will be apparent upon the slightest examination, of a continual repetition of the same figure. This figure, whatever it be, so far as it consists of a single colour, is engraved upon a copper roller, the length of which corresponds with the breadth of the calico, and the circumference of which corresponds with the length of the pattern. In general, in such cases, the breadth of the pattern being very much less than that of the cloth, it is repeated many times in the width

This pattern is therefore engraved upon the surface of the roller, the length extending completely round it, and being repeated throughout the length of the roller in the same manner as it is intended to appear on the cloth. This roller receives the colouring matter by a certain apparatus which first smears, and then wipes it, so as to remove all dye except what fills the incisions of the engraving. The cloth is then passed between this roller and another which has a soft surface, the two being pressed severely together in their line of contact. By this process the colour deposited in the lines of the engraved roller is transferred to the cloth, and the printing is completed. When patterns in two colours are to be printed a second engraved roller is provided, carrying upon it the pattern corresponding to the second colour, and the cloth, after having been printed with the first colour, is made to pass in contact with this second roller, so that the pattern of the second colour is transferred to the cloth from the roller, in the same manner as that of the first, and the movement of the cloth is so nicely regulated, that the pattern of the second colour falls into its place, with reference to that of the first colour, with the greatest imaginable precision. Where patterns of three colours are to be printed, a third roller is in like manner provided and worked.

Until lately calico has not been printed by these means in more than four or five colours at once. At the Great Exhibition, however, a beautiful machine was shown by Messrs. Mather of Salford, by which a pattern consisting of eight colours could be printed by a single operation, and means for afterwards drying the cloth were also provided.

The cloth has then to undergo several processes of washing and drying, and is finally prepared for sale. The nature of the design printed upon it, differs necessarily with that of the purpose for which it is intended.

Probably no class of designs, and no description of colour, has been so popular and so useful as the homely lilacs, called Hoyle's prints.

The cylinders upon which the design is engraved are prepared in a very interesting way. The following explanation will, it is hoped, render intelligible the mode of producing these engraved rollers at a trifling expense:—

Let us suppose that the length of the pattern, and consequently the circumference of the roller on which it is to be engraved, is limited to six inches. This length, however, is immaterial so far as the principle is concerned. A small roller then, of soft steel, is taken, whose circumference is six inches, and whose length is equal to the width of the pattern. Upon the surface of this roller the proposed pattern is engraved by the ordinary process of engraving. This steel roller, with its surface thus engraved, is then hardened by a certain process; it is next placed in contact with another roller of soft steel, against which it is urged by the action of a powerful press, and the one roller being rolled upon the other the surface of the soft roller takes *in relief* an exact impression of the *intaglio* pattern which was previously engraved upon the original roller. This second roller, thus having upon it the pattern in relief, is then hardened, and is rolled upon the copper cylinder to be engraved, urged against it in like manner by the action of a powerful press, and leaves upon it the engraved characters. These rollers being repeatedly applied to the copper cylinder throughout its entire length, the engraved pattern is reproduced in the same manner as it is intended to be printed upon the cloth.

By this ingenious plan the enormous expense of engraving separately each roller is obviated, and a means provided for multiplying, if it were necessary, the original design to an indefinite extent. Worn-out

rollers can be used over and over again, by being simply turned smooth in a lathe, and then impressed as before. Such is the productive power of the machinery now noticed, that a single machine, attended by a man and a boy, is capable of printing as much calico per hour, in four colours, as would require the labour of 200 men to effect by the old method of block-printing! A more striking instance of the economy effected by the application of machinery to industrial purposes could scarcely be conceived.

CHAPTER IV.

MANUFACTURING MACHINES—CONTINUED.

Section II.—Paper and Printing Machinery.

In considering the subject of the present chapter, the general arrangement adopted in the preceding one will be observed. The production of the material will receive our attention first, and the uses to which it is applied subsequently. The general principle of paper-making is one not difficult to be understood. The end to be accomplished is to produce, out of fibrous substances, a sheet of material held together by the mutual cohesion of its parts, and the interlacement, to a certain extent, of its fibres. Let us suppose a piece of a rope cut into the very finest shreds, and mixed with water, to which a little glue or starch has been added, and it will not seem a very difficult task to produce out of such substances the material required. All that would be necessary would be to spread out the semi-fluid mass into a thin sheet, to drain away the water, and to dry the substance left. It would be a coarse sheet ot paper. The fundamental principles, therefore, of all paper-making machinery consist in the reduction of fibrous materials to a minute state of division, uniting them with water and some glutinous substance, distributing the mass thus produced into a sheet, and drying the

latter after the removal of the superfluous water. Paper made in the rude way just described, would necessarily exhibit all the imperfections arising from the nature of things, but it would be as strictly paper, in the proper sense of the term, as the best product of the most refined mechanism. And it is to be observed, that paper made in this way has been formed for centuries by the Hindoos and Chinese. The Hindoos, by pounding hemp fibres in machines worked by the feet, and with very little mechanical aid, have produced for a long period the most beautiful paper, very fine in quality, and very smooth and uniform in texture. The Chinese, by macerating the bark of a tree, and subsequently reducing it to a pulp, likewise succeeded, at a very early time, in producing a very fine kind of paper, and the same manufacture is continued by them to the present time. At the Great Exhibition, specimens of paper made by the Hindoos, of various qualities, were shown; and among them were nine different kinds, made at one large paper manufactory, in which not fewer than two thousand labourers are employed.

But although, theoretically, the principles of paper-making are very simple, yet the production of paper in a continuous sheet, and in such quantities, and of such qualities, as the great wants of a commercial state require, demands a high exercise of mechanical and scientific skill. And many years of laborious application have been necessary to bring to perfection the beautiful paper-making automaton we are about to describe.

The preparatory processes in the manufacture of paper are necessarily very few and simple, consisting merely of the reduction of rags, and other fibrous substances, to a very fine state of division, and then removing from them all foreign matters, colouring matters included. The machine first employed is for the purpose of tearing the rags into fine shreds, and at the same time removing

their impurities. It consists of a large reservoir, partly filled with water, which is admitted by a tap, and kept running during the process. Across the vat a shaft runs, which carries upon it a wooden cylinder armed with teeth of steel, and at the bottom of the vat is a hollowed piece of wood also armed with teeth, and these parts of the engine are so adjusted, that when the rags pass between them they are caught and torn into shreds. An adjustment of the shaft also enables the upper teeth in the cylinder to be brought into closer or more distant relation with those below. Thus the rags can be torn into coarser or finer shreds, or they may be progressively torn from a large size to the smallest. The cylinder armed with teeth is driven at a rapid rate by a band from the main shaft impelled by the steam-engine. The water and rags being introduced, this cylinder is made to revolve, and the rags are violently torn and thrown about in the water, thus separating the impurities, which fall to the bottom, and are removed through a perforated opening there. The operation of the engine is continued until the rags are reduced to a fine state of division, and are now called pulp. During the whole time water is continually flowing through the reservoir, but in diminishing quantities, and the impurities are drained away through wire-covered openings, the pure pulp and water alone remaining at last.

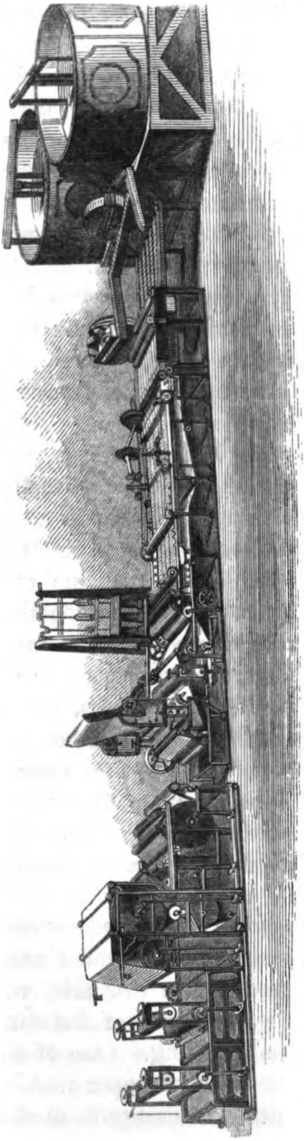
The rags are now thoroughly disintegrated, but they are unfit for making paper in consequence of the dirty appearance of the pulp. The object of the next process, therefore, is to remove the colouring matter, and to render the pulp of a pure white appearance. If, however, only pure white linen rags have been employed in manufacturing the pulp, this bleaching is not only unnecessary but even injurious, and the pulp requires only a continuance of this preparation for the manufacture of paper. When variously coloured rags are

used, or old writing paper, and such like materials, then the bleaching process is indispensable.

By a large pipe communicating with the pulp-engine, the semi-fluid mass is allowed to flow away into a reservoir, where it undergoes the bleaching process. This is effected with very little mechanical assistance. The pulp is placed in cisterns, and mixed with a solution of chloride of lime. By this powerful chemical agent, the colour is in a little time entirely removed, and the pulp becomes bleached white. When this has been accomplished, the pulp is pressed in the hydraulic press so as to reduce its bulk. It is then again washed, so as to remove the chloride of lime, and the final process is now commenced.

The state of the rags as they leave the first pulp-engine is that of a moderately finely divided mass, but in order to produce paper, they require to undergo a still more minute division. This is effected in another pulp-machine called the beater. This machine only differs from the first in the teeth being set closer together, and in the cylinder being made to revolve at a much higher velocity. The whole mass is subjected to the powerful action of this machine for some hours, and so much latent heat is extricated that the pulp becomes very sensibly warm, and is reduced to the last state of fineness. When this condition is attained, the pulp is now fitted for the production of paper, and is let off to the vat, from which it is supplied to the paper-making machine.

At the Great Exhibition were exhibited several models of this beautiful machinery, and in the French department a full-sized machine, made in Paris, was shown, but not in action, in consequence of the difficulties inseparable from the undertaking. One of the most beautiful and complete systems of paper making was, however, illustrated by the magnificent models



sent by Messrs. Bryan, Donkin & Co., the firm connected with the history and improvement of this machinery from its first introduction. Of this beautiful series of models we were permitted to take photographs, and the accompanying engraving represents the manufacture of paper by them. It exhibits the progress of the manufacture from the pulp to the continuous sheet.

The pulp is discharged first into two large reservoirs furnished with revolving arms or agitators, which stir up the mass and prevent its settling at the bottom. From these vats the pulp is conducted into an apparatus called a pulp-meter. This is an ingenious machine for insuring uniformity in the supply of pulp to the rest of the engine. It consists of an arrangement of revolving buckets in a circular box, this box is filled with pulp, and as the buckets dip into it, they take up a certain quantity, which they then discharge in succession into a trough communicating with the first part of the

machinery. In all processes where a continuous sheet is formed, as in cotton carding, and wool carding, &c., it is found greatly to secure the uniformity of the sheet, if the machine be supplied with measured quantities of the material, and for this purpose it is generally weighed out, and then supplied to the machine. The application of the same principle to the paper engine is of recent introduction, and promises to be attended with equal success.

The pulp is then conducted from the meter to the strainer. As it passes along the trough a little channel of water from another machine, identical in its action with the pulp-meter, is added to it. This water serves to dilute the pulp to a proper consistency for future operations. The diluted pulp then flows in a single channel to the sand-strainer. This is a trough in which a series of furrowed ridges of metal are arranged, over which the pulp flows in its onward progress. In thus flowing onwards it deposits its heavier impurities, which settle at the bottom of the trough, and the pure pulp, which is of lighter specific gravity, flows forward.

When the pulp has reached the end of the sand-strainer, it flows down into a strainer called a knot-strainer. This is very differently constructed to the preceding. It consists of a trough containing a number of brass bars placed close together longitudinally, and most accurately planed and smoothed. These bars are in a movable frame, which is agitated at each side by a lever, and the bars are so closely set together as to permit nothing but the fibre of the paper to pass between them. Any knots which may have been in the pulp are removed and left on the upper surface of the bars, while the pulp filters down into a box placed for its reception. As these knots accumulate they are taken away by an attendant.

The pulp is then again strained or filtered, and this

time by ascension. Passing from the preceding strainer down into a metal box, it is carried forward to a third trough, in which bars similar to the last named, but inverted in their position, are placed. The pulp now filters upwards through these bars, and being now devoid both of all impurities and of all inequalities of texture, it is fit for the beautiful process to which it is about to be submitted.

Proceeding from the last strainer it flows over a leather lip into a little trough containing a two-bladed agitator, called a hog. This agitator effectually stirs up the pulp, and keeps it from settling down at the bottom. It is then conducted on to an endless apron, made of perforated brass wire. Here the pulp first begins to part with its water, which streams down through the wire into a wooden reservoir placed underneath. But this water contains a small portion of the finer fibres of the pulp, and the material is too valuable to be wasted. It is therefore made to run out of this reservoir into a trough, which carries it back to the engine employed to dilute the pulp coming from the pulp-meter with water. Thus the waste water from the pulp is used over and over again, and it would appear scarcely possible that any of the material should be wasted. The wire apron being continually moved forward, receives a continuous supply of pulp, and carries it onwards. In passing on with the apron the lateral edges of the pulp are confined, and made parallel by a band lying on the apron on each side, called a deckle band. These bands move with the apron, and the pulp finally leaves them, its edges being now tolerably firm and well defined. As the pulp passes along the wire web, the latter is shaken so as to facilitate the escape of the water. In proportion as it increases its distance from the strainers, the pulp becomes more and more firm by the constant loss of its watery parts, but it is even at the end of the wire cloth very soft and friable.

The marks called watermarks are now to be produced in the paper, if it should be intended to receive any. These marks consist, in fact, of a displacement of a portion of the pulp where they appear thinnest, by the pressure upon it while yet soft of a wire roller, upon which different devices are wrought. These devices are then reproduced in the substance of the paper, just as sealing wax receives the impress of a seal. And no matter what may be their variety, the soft pulp receives and retains it faithfully. In this way the marks of the maker's name, or of crests of various kinds, or of straight lines, as in cream laid and foolscap paper, or of irregular lines, as in paper with waved marks, are produced. This is effected in a very simple way. Just before the paper leaves the wire cloth, it passes under a roller made of brass wire, upon the surface of which the device is produced, by wires wrought into it, and the impress of this roller communicates itself to the paper.

Just prior to the pulp leaving the wire web, a very ingenious arrangement is made in the machine, with a view more perfectly to extract the water. It consists of a metal box placed under the travelling web, and communicating with three powerful air-pumps. These pumps are set in motion by the steam-engine, and produce a powerful exhaust or vacuum in the box. The effect of this on the superincumbent layer of pulp is to suck in the water, and to cause the fibres very completely to interlace one with another. The firmness of the texture of the paper is thus very materially promoted.

The paper now passes between two rollers upon a web of felt, leaving the web upon which it was produced, which returns for a continual fresh supply. These rollers are covered with felt, and squeeze out a considerable quantity of water, and the paper now becomes

pretty firm. It is, however, still wet and unfit for any useful purpose, and it is therefore carried on between other rollers, which give it additional pressure, but no amount of force which could be exerted by cylinders would be capable of entirely removing the water, and rendering the paper dry and firm.

An additional force is therefore now summoned by the manufacturer. The damp but tolerably smooth sheet is received by a large cylinder revolving on its axis, but charged with high-pressure steam. The heat thus communicated dissipates the moisture as steam, and the paper becomes rapidly very nearly dry. In order, however, to complete it, it passes over several other cylinders similarly heated, and finally emerges from the last of the series a beautifully white, smooth, and continuous sheet.

There are two great elements of success completely embodied in this wonderful automaton. In all manufacturing arts, one of the most important considerations is continuity of production. That manufacturing machine is the most perfect, and the most economical, which is capable of uninterrupted productiveness. Wherever the material to be manufactured can pass without interruption, (and consequently without delay,) from the first to the last stages of its treatment by machinery, there will be in all probability a better article produced, and at a less cost, than where at every stage it has to be carried from one place to another. No machine yet invented exhibits this more strikingly than that just described. It is a complete system, for the raw material enters at one extremity, and the finished product emerges from the opposite end.

In a second point also this machine exhibits its admirable construction, which is in its being entirely automatic. It requires no powers for its perfect performance which are not vested in it. It receives no

help from man, but accomplishes its allotted task by the combination and appropriate operation of the parts of which it is made. If assistance is necessary in any respect, it is in order to remove accidental difficulties, and not for the purpose of aiding in the manufacture. The action of the machine is also very rapid, the progress of the pulp from the first strainer to the finished roll of paper not generally occupying more than a few minutes.

When the paper is required to be glazed, it is effected by passing it between polished and heated cylinders, in passing through which it is subjected to the most severe pressure. The effect of this and the heat is to produce a very fine and smooth surface. The paper is then ready for any of the varied purposes to which it is to be applied. It is a curious fact that the friction used in glazing paper between cylinders develops so much electricity that a ductor blade is necessary to detach the paper from the cylinder, to which it would otherwise closely adhere.

It will be obvious that by mixing any substances such as gelatine, starch, or colouring matter, with the pulp, the quality and colour of the resulting paper is affected accordingly. The finer kinds of paper are generally impregnated with gelatine or size after the paper is made. It has been found that mixing the gelatine with the pulp in the process of manufacture injured the felt used in the machine; and it has, therefore, as far as possible, been accomplished out of the vat. Sizing in the vat, however, offers many advantages when substitutes for gelatine can be used. Of these, several kinds are employed. A mixture of alum and rosin previously dissolved in soda, and combined with potato-starch, is now largely used for sizing in the vat by the continental makers. Paper thus made is less greasy to write upon, but does not bear the ink so well

as those which are sized with gelatine. For writing-papers in England the application of gelatine by an after process is still preferred, and is accomplished by means of rollers dipping in a trough of the size. At Mr. Joynson's mills, in Kent, fine writing paper is now made, sized with gelatine, dried, and cut into sheets at the rate of sixty feet a minute in length, and seventy inches in width. Two machines at these mills turn out twenty-five tons of paper every week. At another of the great paper mills 1,400 tons of paper are produced yearly, the Excise duty upon which exceeds 20,000*l.* per annum.

In Great Britain alone about 130,000,000 pounds weight of paper are annually manufactured—estimated as worth upwards of 3,000,000*l.* sterling, and yielding to the revenue 870,000*l.* Nine-tenths of this quantity are consumed in this country, the exports not amounting to more than 300,000*l.* The number of mills in this country at work in 1851 was 380; the annual production amounted in 1850 to 62,960 tons.

The Great Exhibition contained a variety of different specimens of paper of very opposite appearance and qualities. Mr. Joynson exhibited a roll of paper 2,500 yards in length; thus proving the perfection of the machinery which converts the water-suspended pulp, flowing continuously at one end of the machine, into an unbroken sheet of well-sized writing paper, which comes out dried and ready for use at the other end. They also displayed a sheet of brown paper, 93 inches in width, and 420 feet in length, besides mill-boards of a new kind, and specimen reams of writing paper. Mr. Fourdrinier exhibited a sheet of pottery paper, two miles and a half in length. This paper is employed in the potteries as a vehicle to receive the impressions from the engraved plates, to be transferred therefrom by the burnishers to the unglazed ware. This class of paper

is of great strength, and, in illustration of this, we may mention an anecdote which occurs to us. With this paper, twisted into a rope, the proprietor of one of our potteries repaired, rapidly and efficiently, the broken traces of a carriage which had conveyed a party of friends over the rough road leading to his works. The strength of this paper was also exhibited in a single sheet 20 inches in width, to which four half-hundred weights were suspended.

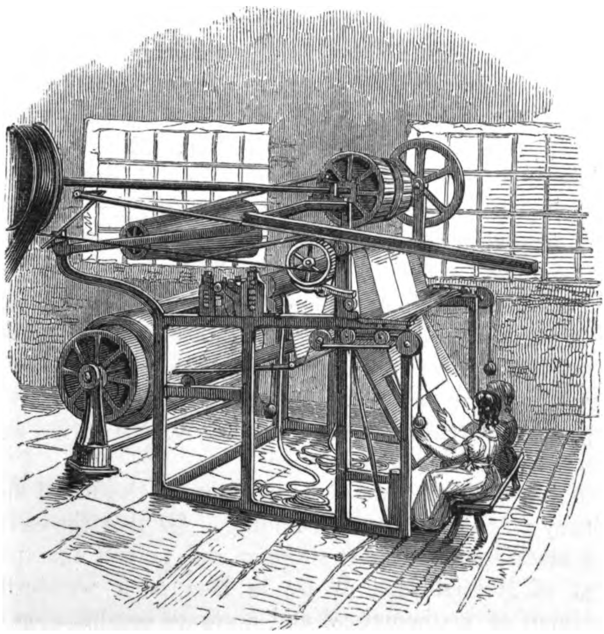
Some of the novel papers invented by Mr. Oldham, and manufactured by Mr. Saunders, were placed against the glass partition which divided off the machinery, and they produced effects very similar to the celebrated porcelain pictures, and were necessarily much more easily produced, were cheaper, and not so liable to receive injury. Among the water-marks shown in the paper are some illustrations of sculpture from Nineveh, some Roman heads, the Madonna and Child, rural scenery, a medallion of her Majesty, the Exhibition building, with portraits of her Majesty and Prince Albert, a view of York Minster, and various others. The invention appears to be admirably adapted for paper for bank notes, and other descriptions in which security from fraud or forgery is desired.

Beautiful paper of a very pure kind was exhibited by a foreign maker, of the Souche paper mill. This paper was bleached without chlorine, and exhibited very delicate and beautiful colours. There was also some fine filtering paper, which, in consequence of the extreme purity of the Souche waters, is almost entirely devoid of all earthy matters. A thousand grains of this paper, when burnt, would only leave behind three grains of ashes. There was also a curious paper shown, which was called "*parchemin végétal.*" It was shown by French exhibitors, among whom was one of the celebrated firm of Montgolfier. Some of the specimens of this paper were

prepared with a sort of oil varnish, and were extremely strong and tenacious. The paper was used for making cartridges for artillery, for if it took fire accidentally, the fire did not spread as in paper, but went out almost immediately. This paper is used for binding instead of parchment, and it has also been employed for spinning mills and for the uses of the gold-beater. Paper made from straw and other materials was also shown. There was also a paper made in a peculiar manner, of one side variously coloured from the opposite. Thus, one side was white, and the other a dark blue. The manner in which this paper was made was the following:—Two webs of paper are made separately, and by passing them while wet in contact through a pair of rollers, they became firmly united, and are then dried as usual. This kind of paper is much used in copper-plate printing, the upper surface of the paper being of a much finer texture than the under. In the manufacture of paper for postage envelopes, silk thread is introduced into its substance in a somewhat similar manner. Specimens of paper have been sent to the writer which are perfectly waterproof. They are manufactured at a paper mill in the vicinity of the metropolis, and are of different thicknesses. For a variety of purposes such paper seems to be a useful material. It is of a light yellow colour, and is apparently impregnated with oil and rosin.

A very interesting kind of paper has also recently been introduced, under the name of Iridescent Paper, by Messrs. De la Rue. This paper exhibits all the beautiful play of colours of the peacock's tail, yet, singular to add, these colours do not really exist in the paper, but are produced by the state of its surface. The principle upon which these colours depend is that which was explained by Sir Isaac Newton, in accounting for the beautiful prismatic colours exhibited by a soap bubble,—namely, the extreme thinness of the film. This

paper is made in the following way, under a patent. A few drops of colourless varnish are dropped upon water, and a sheet of paper is laid upon the film thus formed. The paper immediately becomes covered with the film, which adheres to it, and it is then removed and dried. A piece of paper, formed in the shape of a shell, and appropriately coloured, bears the most singular



resemblance to the natural object. This simple but ingenious process is also applicable to the embellishment of metallic surfaces as well as paper or card.

When the paper leaves the machine, it is required to be cut into sheets, and various contrivances for effecting this object have been introduced; one of these is M. Fourdrinier's, represented in the cut. Its principle

is extremely simple. The paper to be cut, is taken from the roll and carried forward, being presented in its course to circular knives, which divide it in the middle longitudinally, and also take off a thin ribbon at the edges. The division into sheets is effected by the stoppage of the web for a few seconds, during which a knife descends and cuts it across. The paper then continues passing down until a fresh length is measured out, when the knife again descends, and another sheet is removed. In this manner the whole roll is measured out and cut into a suitable size. This is also effected by a machine attached to the paper-engine, which cuts the sheets from the roll as it leaves the tram cylinders.

There is a variety of machinery of simple construction used in the cutting of paper, card-board, &c., but not very deserving of more than a passing notice. Several of these were exhibited in 1851. The paper-ploughing and planing machines, invented by Mr. Wilson, resemble a planing-machine for other substances in its general principles. Paper is, in fact, cut in the same manner as any other hard substance, being compressed to such a degree as to render it very resistant to the cutter, and capable of bearing a clean edge.

Of much more general interest is the beautiful machinery employed for paper-folding. Of this the envelope machinery is a most singular and perfect example. That of Messrs. Hill & De la Rue is a wonderful specimen of mathematical and accurate combination of parts, and is probably one of the most efficient machines in operation in any manufacture whatsoever. The following is the action of this machine. The feeding-boy places the previously cut blank envelopes on a small platform, which rises and falls in the rectangular recess formed by the cylindrical axes of the folders (shown open in the engraving); the bearings of the folders serving by their elongation to guide the envelope into its

place at the moment of the small platform falling. A plunger now descends and creases the envelope by carrying it between the folder-axes, at the same time turning the flaps upwards in a vertical direction: the plunger, which descended as a whole, now divides into two parts, the ends rising and the sides remaining down to hold the envelope until the end-folders have operated; these latter turn over the flaps, the one on the right

of the feeding-lad taking a slight precedence, and being closely followed by the gumming apparatus, which takes gum from an endless blanket working in a trough, and after applying it to the two end flaps, retires; at the same time the remaining half of the plunger moves upwards, to allow of the side folders turning over the remaining two flaps, the folder nearest the feeder taking precedence. During these operations, the end-folders have remained at rest, and the whole four open simultaneously. The taking-off apparatus, with its fingers tipped with vulcanized caoutchouc, now moves forward over the folded envelope, which is lifted upwards by the rise of the small platform and retreats with it, placing each envelope, as it is successively folded, under those which have preceded it. The envelopes are now knocked over on to an endless blanket, and are conducted by it between two cylinders for a final squeeze, and then rise

in a pile up the trough, seen against the right arm of an attendant, who is represented in the engraving as fetching away the folded work. There is a provision in the machine by which the gummer is prevented placing gum upon the platform, in case the feeder omits feeding in an envelope. This machine works at the rate of 2,700 envelopes per hour, and although superseding hand-labour in folding, it is satisfactory to find that, instead of displacing hands, its introduction, by extending the consumption, has, in reality, created work for more than it has displaced.

In March 1845, Mr. Edwin Hill and Mr. Warren De la Rue took out a patent for cutting and folding machinery. Until this period, envelopes had been folded by hand, by means of a bone "folding-stick," an experienced workwoman folding about 3,000 per day.

Another very interesting and most ingenious piece of machinery was also exhibited on the same occasion, for a similar purpose. This machine was invented by a M. Rémond of Birmingham. It differs essentially from the envelope machine exhibited by Messrs. De la Rue. In Rémond's simple contrivance atmospheric pressure is employed for the purpose of raising singly each sheet of paper, and placing it on the top of the folding apparatus; and, again, in giving the necessary inclination to the flaps of the envelopes previously to their being folded down by the action of the plunger. In order to understand the process, we may suppose that several hundred pieces of paper of the required size and shape are placed in readiness on the feeding table of the machine, which, by a very simple operation is started by the girl in attendance at pleasure. The top sheet is raised from the rest by means of a contrivance called a "finger," the underside of which is perforated, and a partial vacuum being formed, each sheet is sucked up against its under surface, and trans-

ferred to the folding apparatus, on reaching which, the exhaustion being no longer maintained, the sheet drops into its place. The folding apparatus consists of an open box or frame, the size of the required envelope, over which is fixed a creaser or plunger, fitting the inside of the frame. The blank piece of paper having been placed on the top of the box by the feeding-finger previously described, the plunger descends just within the box, and the flaps of the envelope are thus bent to a right angle. The bottom of the creasing-frame or box is perforated to prevent any atmospheric resistance on the entrance of the paper, and the passing back of the plunger leaves the paper within the frame with its four flaps standing upright. At this point, the second application of the atmospheric action comes into play, for the purpose of giving the flaps of the envelope a preliminary inclination inwards, with a view to fit them for receiving the flat folding pressure of the return stroke of the plunger: to this end, the four sides of the folding-box are perforated, so as to allow streams of air to be forced against the outsides of the flaps of the envelopes, in order that, on the second descent of the plunger, they may all be folded down at once—the interior and under surface of the plunger being suitably formed to cause the flaps to succeed each other in their proper order. In addition to this, certain contrivances are adopted for embossing the outer flap of the envelope with any device required, and also for gumming the lowest flap, as a fastening for the completed envelope. In order to compensate for the continual decrease in the height of the pile of blank papers, and to provide for the upper one always coming in close contact with the lifting-finger when the platform rises, the addition of a spring has been found to be amply effective.

By this machine not fewer than 40 envelopes are produced in a minute, which gives as many as 24,000 per

day, gummed, embossed, and entirely completed for use; if needed, the velocity might be increased. By the ordinary modes of production, the folding, gumming, and embossing, are all separate processes; and as at each of these operations every single envelope must be separately handled, our readers will have a tolerable notion of the economy gained by the use of the machine. The isolation of the different stages of manufacture consequent upon the employment of manual labour adds immensely to the cost of production, the loss mainly arising from the mere removals from one process to another. In embossing by hand, a boy will perhaps get through 8,000 or 9,000 per day, and then there must be an assistant to turn down the flap on which the device has been placed, and arrange the envelopes in separate parcels. During the time that this machine was at work, we carefully examined it, and compared its performance with that of Messrs. De la Rue. And the opinion we were led to form was, that M. Rémond's machine was either defective in principle or very badly constructed, since it very frequently spoiled an envelope: while the other machine did not spoil one out of some thousands.

Before passing on to the consideration of printing machinery, it may be useful to give a short account of a substance connected with the manufacture of paper, and universally known as papier maché. There are two methods of making articles of this kind, to which we may here allude. First, either by gluing or pasting different thicknesses of paper together, or, second, by mixing the substance of the paper into a pulp and pressing it into moulds. The first mode is adopted chiefly for those articles, such as tea trays, &c., in which a tolerably plain and flat surface is produced. Common mill-board, used for the covers of books, may convey some idea of this sort of manufacture. Sheets of strong

paper are glued together, and then so powerfully pressed that the different strata of paper become as one. Slight curvatures may be given to such pasteboard when damp by the use of presses and moulds. Some of the papier maché work-boxes and snuff-boxes are made by glueing pieces of paper, cut to the sizes of the top, bottom, and sides, one on another, round a frame or mould, which is afterwards removed.

Articles thus made of pasteboard have often a fine black polish imparted to them in the following manner:—After being done over with a mixture of size and lamp-black, they receive a coating of a peculiar varnish. Turpentine is boiled down till it becomes black, and three times as much amber in fine powder is sprinkled into it, with the addition of a little spirit of turpentine. When the amber is melted, some sarcocolla and some more spirit of turpentine are added, and the whole well stirred. After being strained, this varnish is mixed with ivory-black, and applied in a hot room on the papier maché articles, which are then placed in a heated oven.

Two or three coatings of the black varnish will produce a durable and glossy surface impervious to water.

Papier maché, properly so called, however, is that which is pressed into moulds in the state of a pulp. This pulp is generally made of cuttings of coarse paper boiled in water, and beaten in a mortar till they assume the consistence of a paste, which is boiled in a solution of gum-arabic or of size to give a tenacity. The moulds are carved in the usual way, and the pulp poured into them; a counter-mould being employed to make the cast nothing more than a crust or shell, as in plaster-cast. In some manufactories, instead of using cuttings of paper, the pulp employed by the paper-maker is, after some further treatment, poured into the mould, to produce papier maché ornaments.

The process of inlaying with mother-of-pearl was invented by Messrs. Jennens and Bettridge, and patented by them eighteen years since. It is a simple process, and does not consist, as some might suppose and as the name indicates, in cutting out the material and inserting the substance inlaid; it is held simply by adhesion. Its application may be thus described:—the pearl-shell, cut into such pieces or forms as may be desirable, is laid upon the article to be ornamented; a little copal or other varnish having been previously applied, the pieces of pearl at once adhere to it; thereafter repeated coats of tar varnish fill up the interstices, and eventually cover the pearl. This extra varnish is then removed, a uniform surface is produced, and the pearl exposed by rubbing with pumice-stone, polishing with rotten-stone, and finally "handing," or polishing with the hand. The process of gem inlaying is another invention by the same firm, and recently patented by them, and is essentially similar to the last process.

The second portion of the subject of this chapter relates to the application of print and colours to the material the production of which we have now considered. Printing upon paper, which has, of course, nothing to do, in the abstract, with the authorship of a book, must be regarded in the light of a manufacture as strictly as calico-printing; and familiar although it is to us as an art, it has received some highly ingenious and remarkable mechanical developments within a few years. Printing by hand need not detain us, since every village contains a press for this kind of work. But printing by machinery takes all the rank of a great manufacture, and differs as much from hand-printing as spinning by machinery from the spinning-wheel of the cottage. There is, however, this to be said, that very excellent and powerful machines are made for printing by hand, and the work they produce is preferable in

point of finish and fineness of impression to that of the best printing power machine. This, however, is not so much our business. Our concern lies with the ingenuities of machinery, and their application on the great scale to the larger requirements of mankind. For our purposes, therefore, the hand-printing press may be dismissed in the present paragraph.

The type of the printing-press has the same relation to paper that the engraved cylinder of the calico printer has to his fabric. It impresses the design. Type, is, however, produced by a very different process from that employed for the copper rollers. It is cast, out of an amalgam of lead, tin, and antimony, in a metal mould. The process is graphically described in the following manner by a recent writer:—With the mould in the left hand, the founder with his right dips his little instrument into the liquid metal—instantly pours it into the hole of the cube, and then, in order to force it *down* to the matrix, he jerks *up* the mould higher than his head; as suddenly he lowers it, by a quick movement opens the cube, shakes out the type, closes the box, refills it, re-jerks it into the air, re-opens it—and, by a repetition of these rapid manœuvres, each workman can create from 400 to 500 types an hour.

As soon as there is a sufficient heap of type cast, it is placed before an intelligent little boy, (whose pale, wan face sufficiently explains the effect that has been produced upon it by the lead and antimony in the metal,) to be broken off to a uniform length; for, in order to assist in forcing the metal down to the matrix, it was necessary to increase the weight of the type by doubling its length. At this operation a quick boy can break off from 2,000 to 3,000 types an hour, although, be it observed, by handling new type a workman has been known to lose his thumb and forefinger from the effect of the metallic poisons.

By a third process the types are rubbed on a flat stone, which takes off all roughness or "*bur*" from their sides, as well as adjusts their "beards" and their "shanks." A good rubber can finish about 2,000 an hour.

By a fourth process, the types are, by men or boys, fixed into a sort of composing stick about a yard long, where they are made to lie in a row with their "nicks" all uppermost: 3,000 or 4,000 per hour can be thus arranged.

In a fifth process, the bottom extremities of these types, which had been left rough by the second process, are, by the stroke of a plane, made smooth, and the letter ends being then turned uppermost, the whole line is carefully examined by a microscope; the faulty types, technically termed "fat-faced," "lean-faced," and "bottle-bottomed," are extracted; and the rest are then extricated from the *stick*, and left in a heap.

Many attempts have been made to accomplish this process by machinery, some with more, others with less success. At the Great Exhibition, some of the most beautiful type exhibited was sent by Messrs. Miller & Richards, of Edinburgh, and this type was cast by machinery patented by one of the firm. This type, which was called "Brilliant," was so minute, that Gray's Elegy, which extends to thirty verses, was printed by it in a space of only three inches and three quarters by three inches. Type has also been formed by machines which cut it out in the cold state. Of such a kind was the Apyrotype Machine, shown in 1851. This machine was patented by its inventor, and was intended to produce type at a single blow out of zinc or copper. It was of very ingenious construction, and was self-acting. Type produced by it is said to last more than sixty times as long as ordinary type, in consequence of the hardness of the surface. The shape of the letter is also said to be more exact. Machinery for dressing the type after it

leaves the first machine was also shown. As yet these inventions have made little progress; and it would seem that the simple and effectual plan hitherto in use is not at present likely to be disturbed by them.

The arrangement of the type for the work of the printer is generally effected by hand, and the persons who put it into order (or "set it up") are called compositors. But machinery has also been introduced into this department of manual labour, as in so many others,—to the present time, however, without success. Nor, indeed, does it appear probable that any machine can execute the task of the compositor so well as his own hands.

At various periods attempts have been made to construct machines to expedite the compositor's work in printing operations. Among the inventions introduced to the world, those of Delcambre, Young, Rosenthal, and others have attracted most attention. Each of these gentlemen succeeded in constructing a machine, which enabled the compositor, by means of keys, to accomplish a given amount of work in a shorter period than it could be done by the ordinary mode of operation; but they all alike laboured under one considerable drawback. They all required, in addition to the touching of the keys, by which the types were brought into the desired order, an amount of labour greater and very different from the usual routine of a compositor's work; for, after the types had been distributed by hand in the usual manner, it was necessary to form piles of each letter, and to place these in the machine, an operation which could only be effected by taking the type up one by one in the fingers; and thus as much (or even more) time was lost in this preliminary work as was subsequently gained by composing by means of keys. Other attempts have, indeed, been made to construct distributing machines, which should likewise arrange the

type in the piles required by the composing machine; but none of the methods invented have in the working proved as quick as the ordinary process of distribution by hand; and this difficulty has hitherto proved fatal.

The problem that remained to be solved was, therefore, the invention of a machine which either should not require the type to be piled up within it, or which should at least effect this without necessitating any additional labour. This Mr. Sörensen has attempted. His machine is not so much an endeavour to improve upon the methods of his predecessors, as it is an original and totally different plan from all preceding ones; the keys, which are a necessary feature in every composing machine, being the only one which his has in common with any other. The piling of the type, to which allusion has been made, is, indeed, also required in Mr. Sörensen's machine; but here it is effected by the machine itself, and without the aid of the hand or even the eye of the compositor. The most difficult point connected with composing-machines might appear to have been solved; but Mr. Sörensen has also been able to effect that which has hitherto been considered impossible; for this machine not only piles up the types, but likewise distributes them by mechanical means, without necessitating any additional labour, the only operation substituted for the usual labour of distributing the type by hand being that of pushing the type line by line into the machine from the pages which have been printed off. We hear, however, that this scheme, like most others, will prove ultimately of but little value.

The machine which gives life to thoughts, and scatters intellectual food or poison through the world—the steam printing-press—has received a variety of alterations and modifications since its first introduction, but remains in essential respects the same. The machine employed in printing *The Times* newspaper may be taken as a model

of steam printing engines, and in their description we shall follow the account given by their late ingenious inventor, Professor Cowper, in conjunction with Mr. Applegath. In order to render our account intelligible, we shall first briefly state what a power printing machine has to do, and how it does it. It has to seize the sheet of paper, to lay it on a resisting surface, to press it against the type, to keep the latter properly inked, and having done this, to return the sheet to the attendant in a printed state. This is done by placing the type, which is arranged into a square, called a "form," in contact with a large roller on which the paper is carried, and then causing it to pass in contact with other rollers made of glue and treacle, and covered with printer's ink, for a fresh charge of ink. Thus printing by steam consists essentially of a combination of movements which present the paper to the type and remove it again, and of another combination of mechanism which fresh charges the surface of the latter after each impression.

The type form was fixed upon a horizontal frame, which was moved by steam power alternately backwards and forwards through a certain space. Part of this same frame was occupied by the inking table, which was constantly smeared with ink by means of a roller called the "ductor roller," under which it was moved. This frame, thus carrying the types and the inking table, and moved by machinery backwards and forwards alternately through a certain distance, was placed under a cylinder or drum, upon which was stretched, by means of tapes, the paper to be printed, the tapes passing over those parts of the paper which corresponded with the margins of the sheet. The inking rollers were also placed over this frame, so that by its motion under them, the inking table, first receiving ink from the ductor roller, then diffused it upon the inking rollers.

By each motion of the table backwards and forwards, the type form was first made to pass under the inking rollers, by which means the faces of the types were coated with ink, and was next made to pass under the cylinder on which the paper was extended, which being pressed upon them, their impression was left upon the paper. While the types thus passed under the paper cylinder, that cylinder revolved in contact with them in accordance with their motion, and each time it thus passed over them, a sheet of paper was printed.

It will thus be understood that by each alternate motion of the frame which carried the type and the inking table, four distinct operations were performed. First, the inking table received a supply of ink from the ductor roller; secondly, it delivered and diffused a corresponding quantity of ink over the inking rollers; thirdly, these rollers spread an equal quantity of ink over the surface of the type; and, fourthly, the types gave their impression to the sheet of paper extended upon the drum or cylinder, and accomplished the operation of printing.

By this improvement the speed of printing was augmented in the first instance from 250 to 1,000 sheets per hour. The first machines of this improved description, which were brought into operation on a large scale, were adapted to the printing of *The Times;* and on the 28th of November, 1814, the public were informed that *The Times* newspaper which was then placed in their hands was the first sheet of paper printed by self-acting machinery.

In a little time, however, even this powerful engine was too feeble for the adequate supply of the immense demand produced, and it became necessary to add to its powers. It was now necessary to have the machine of such power and rapidity of action as to throw off a sheet every second, or about 4,000 sheets an hour. All

the four operations above alluded to had to be accomplished in the short space of that single second, at the expiration of which the sheet was to be delivered printed.

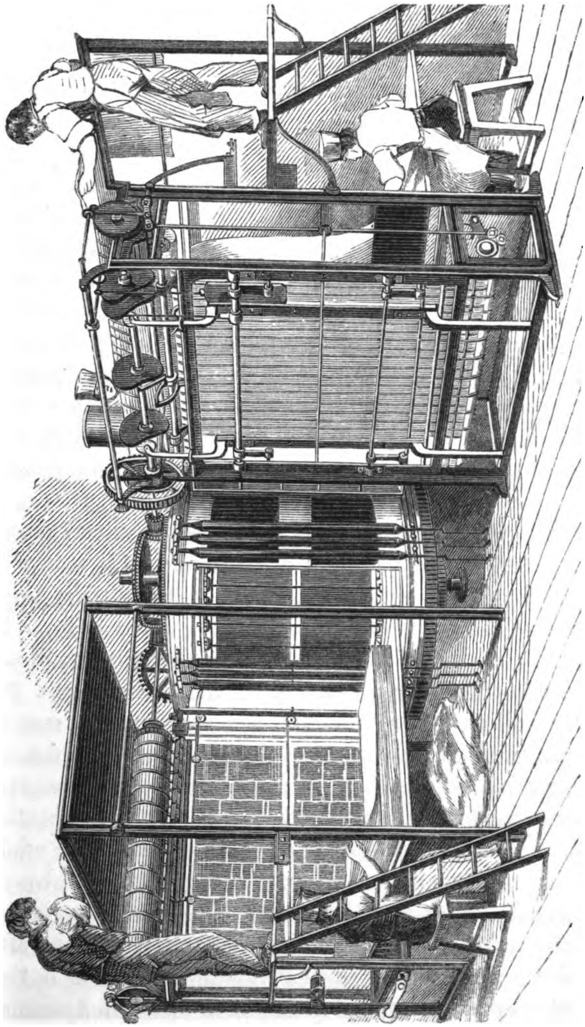
This formidable mechanical problem was solved by the skill and genius of Messrs. Cowper and Applegath, to whom the printing-press had already owed many of the details of its improvements. This increased power, moreover, was obtained without departing materially from the principle of the machine already explained. The type form and inking table were still retained, moving backwards and forwards alternately under the paper cylinders and inking rollers, but the number of cylinders and rollers under which they were moved was augmented. There were now four cylinders on which paper was extended to be printed, and, consequently, there were four sets of inking rollers. Every time the type form was carried from right to left, or from left to right, by the alternate motion, the types were four times inked, and four times delivered their impression to the paper, and, consequently, four sheets were printed, the returning motion of the frame printing four sheets more.

This machine was considered almost miraculous in its operation at the time when it was first put to work. It was superintended by eight persons. It had four delivering tables, on which the blank paper was laid. A sheet was delivered to the machine from each of these tables, was then seized between two fingers, which drew it down between the tapes by which it was carried round the printing cylinder, brought into contact with the types, impressed upon them, carried out, and delivered printed to an attendant; the whole of these operations being effected by self-acting machinery. The duties of the attendants consisted, in fact, merely in supplying the machine, and in removing its perfected productions. The maximum producing power of this machine was 5,000 sheets per hour.

For a number of years this most beautiful engine fulfilled its duties with regularity, and was sufficiently rapid to supply the demands of the occasion. The development of the circulation of the newspaper, however, in time outstripped the capabilities of the machine, and it was found to be insufficient for the wants of the managers. Its productiveness required to be more than doubled. It was, in short, necessary now to provide a machine by which at least 10,000 sheets an hour could be worked off from a single form. The proposal appeared at first impossible of execution, for it is found that sheets so large as newspapers cannot be delivered with the necessary precision to the machine by hand at a more rapid rate than two in five seconds, or twenty-four per minute, being at the rate of 1,440 sheets per hour. Now, in this manner to print at the rate of 10,000 per hour, would require seven cylinders, to place which so as to be acted upon by a type form moving alternately in a horizontal frame as before described, would present mechanical difficulties almost insurmountable.

The ingenious idea now suggested itself to Mr. Applegath of placing the form of type upon a revolving cylinder, and thus exchanging the reciprocating motion, with all its disadvantages, for continuons movement. This idea was ultimately successfully carried out, and the vertical printing machine was the wonderful automaton in which it resulted. This machine, which is represented in the cut, we shall now endeavour to explain.

A large central drum is erected, capable of being turned round its axis. Upon the sides of this drum are placed vertically the columns of type. These columns, strictly speaking, form the sides of a polygon, the centre of which coincides with the axis of the drum, but the breadth of the columns is so small compared with the diameter of the drum, that their surfaces depart very little from the regular cylindrical form. On another



part of this drum is fixed the inking table. The circumference of this drum in *The Times* printing machine measures about 200 inches, and it is consequently 64 inches in diameter.

This drum in *The Times* machine is surrounded by eight cylinders, also placed with their axes vertical, upon which the paper is carried by tapes in the usual manner. Each of these cylinders is connected with the drum by toothed wheels in such a manner that their surfaces respectively must necessarily move at exactly the same velocity as the surface of the drum. And if we imagine the drum thus in contact with these eight cylinders to be put in motion, and to make a complete revolution, the type form will be pressed successively against each of the eight cylinders, and if the type were previously inked, and each of the eight cylinders supplied with paper, eight sheets of paper would be printed in one revolution of the drum.

It remains, therefore, to explain, first, how the type is eight times inked in each revolution; and, secondly, how each of the eight cylinders is supplied with paper to receive their impression.

Beside each of the eight paper cylinders are placed eight sets of inking rollers; near these are placed two ductor rollers. These ductor rollers receive a coating of ink from reservoirs placed above them. As the inking table attached to the revolving drum passes each of these ductor rollers, it receives from them a coating of ink. It next encounters the inking rollers, to which it delivers over this coating. The types next, by the continued revolution of the drum, encounter these inking rollers, and receive from them a coating of ink, after which they meet the paper cylinders, upon which they are impressed, and the printing is completed.

Thus in a single revolution of the great central drum, the inking table receives a supply twice successively

from the ductor rollers, and delivers over that supply eight times successively to the inking rollers, which, in their turn, deliver it eight times successively to the faces of the type, from which it is conveyed finally to the eight sheets of paper held upon the eight cylinders by the tapes.

Let us now explain how the eight cylinders are supplied with paper. Over each of them is erected a sloping desk, upon which a stock of unprinted paper is deposited. Beside this desk stands an attendant, who pushes forward the paper sheet by sheet towards the fingers of the machine.

These fingers, seizing upon it, first draw it down in a vertical direction between tapes until its vertical edges correspond with the position of the axis of the printing cylinder. Arrived at this position, its vertical motion is stopped by a self-acting apparatus provided in the machine, and it begins to move horizontally, and it is thus carried towards the printing cylinder by the tapes. As it passes round this cylinder it is impressed upon the type, and printed. It is then carried back horizontally by the same tapes on the other side of the frame, until it arrives at another desk, where an attendant awaits it. The fingers of the machine are there disengaged from it, and the attendant receives it, and disposes it upon the desk. This movement goes on without interruption; the moment that one sheet descends from the hands of the delivering agent, and being carried vertically downwards, begins to move horizontally, space is left for another, which he immediately supplies, and in this manner he delivers to the machine at the average rate of two sheets every five seconds, and, the same delivery taking place at each of the eight cylinders, there are sixteen sheets delivered and printed every five seconds.

It is found practical that by this machine in ordinary work between 10,000 and 11,000 per hour can be

printed; but with very expert men to deliver the sheets, a still greater speed can be attained, and it is not uncommon to work off 12,000 or 13,000 sheets per hour. Indeed, the velocity is limited, not by any conditions affecting the machine, but by the power of the men to deliver the sheets for its consumption.

A number of mechanical difficulties presented themselves in perfecting this machine. It was difficult to adjust it so as to keep what is called register, that is, so that the columns on one side should be exactly opposite to those on the other. The accomplishment of this was no easy task; for it was found that if by any error in the delivery or motion of a sheet of paper, it arrived at the printing cylinder one-sixtieth part of a second too soon or too late, the relative position of the columns would vary about an inch. In that case the edge of the printed matter on one side would be one inch nearer to the edge of the paper than on the other side. This, however, was overcome, and it is stated that the new machine spoils less paper than the old one, while in the same time it nearly trebles the amount of work done.

It would seem scarcely possible that a higher rate of speed in printing than 10,000 or 12,000 sheets in the hour could become necessary. But it is rash to come to any definite conclusion, when we review the almost miraculous progress made in this respect. If, however, a higher rate of production is required, unlike the old machine, the powers of the present are scarcely to be limited. In such a case, all that would be necessary would be to enlarge the central drum carrying the types, so as to be able to surround it with a greater number of printing cylinders.

The following are interesting statistics relative to the printing of *The Times*:—On the 7th of May, 1850, *The Times* and *Supplement* contained 72 columns, or 17,500 lines, made up of upwards of 1,000,000 pieces of type,

of which matter about two-fifths were written, composed, and corrected after 7 o'clock in the evening. The *Supplement* was sent to press at 7·50, P.M., the first form of the paper at 4·15, A.M., and the second form at 4·45, A.M.; on this occasion 7,000 papers were published before 6·15, A.M., 21,000 papers before 7·30, A.M., and 34,000 before 8·45, A.M., or in about 4 hours. The greatest number of copies ever printed in one day was 54,000, and the greatest quantity of printing in one day's publication was on the 1st of March, 1848, when the paper used weighed 7 tons, the weight usually required being 4½ tons; the surface to be printed every night, including the *Supplement*, was 30 acres; the weight of the fount of type in constant use was 7 tons, and 110 compositors and 25 pressmen were constantly employed. The whole of the printing at *The Times* office is now performed by four of Applegath and Cowper's four-cylinder machines, and two of Applegath's new vertical cylinder machines.*

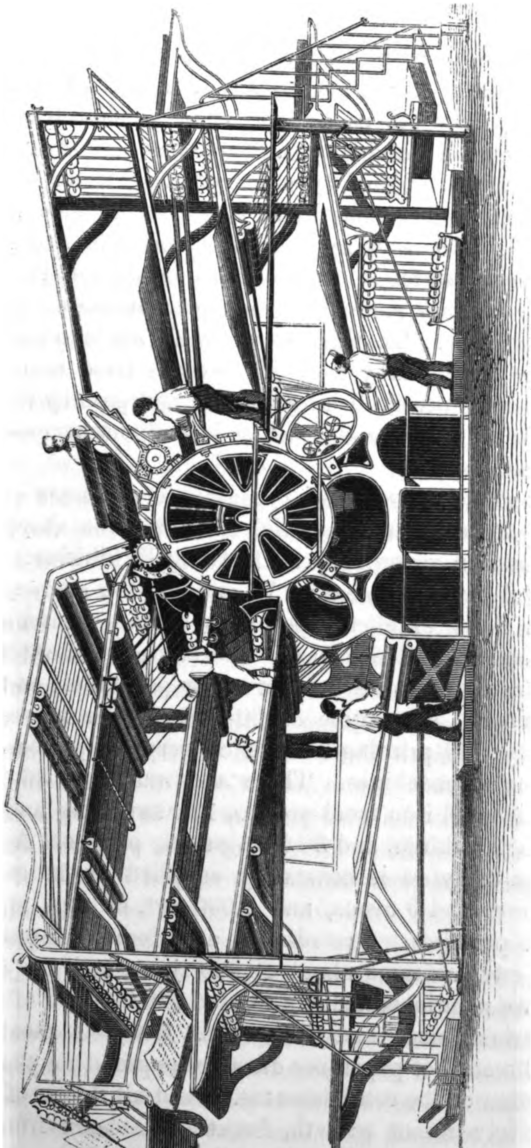
In America attempts have also been made to expedite the productive powers of the steam-press, and in that country, where the popular avidity for reading newspapers and other publications is so excessive, such machinery has become indispensably necessary. If we are to give implicit credit to the statements made in one of the American papers, they have in use in New York, a printing press capable of producing 20,000 sheets an hour. The following is their own account of this machine:—

"On Jan. 29, 1851, 20,000 copies an hour of the *New York Sun* were printed at the steam-press figured in the engraving. The press is 40 feet in length, 20 feet in height, and consists of two stories, the second

* For the information contained in this and some preceding pages, the writer is indebted to the late Professor Cowper, and to the managers of *The Times* paper.

of which is reached by a flight of iron stairs. The type, by means of a wedge-like shape of the rules, is secured upon the outer surface of a large drum or cylinder, to which the paper is drawn in from eight feeding-places. As the drum revolves, it gives at each revolution eight impressions from the type, and the sheets, as fast as they are printed, are caught at eight discharging places by a contrivance called flyers, and laid down as evenly one upon the other as they would be by hand. The press has 1,200 wheels, 400 pulleys, 202 wooden rollers, 400 tape-guides, 6,000 bolts and screws, a multitude of braces, arms, and cog-wheel connexions, and, to convey motion to all, 500 yards of belting. In front of the machine is a register, which notes in plain figures every impression, and adds up the sum as fast as they are printed; and within the hours of 9 and 12, daily, between 50,000 and 60,000 copies of the *Sun* are thrown off by this giant worker, aided by 16 hands, and which, with their help, does as much work an hour as by the old mode would have required the employment of 6,000 men. This machine, set up in the press-room of the *Sun*, a fireproof vault 140 ft. in length and 20 ft. in width and height, cost 20,000 dollars." An examination of the engraving will show that the machine in question is constructed on similar principles to Mr. Applegath's, with this exception, that the type-drum is horizontal instead of vertical. It is an interesting specimen of Transatlantic machinery, and if the statement as to its powers be correct, it is certainly one of the most powerful printing presses in the world.

Before drawing the present chapter to a close, we may just glance at a few processes connected with our general subject. Stereotyping is among these, and deserves notice as a rapid, ingenious, and successful method of reproducing the type form without its having to undergo



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composition. It is effected in the following simple way:—A cast of the arranged type is taken in plaster of Paris: from this cast a copy is then taken in melted metal, and the metal copy thus obtained answers almost as well as the original type for printing from. What imperfections there may be in it are either remedied or removed. Electrotyping is another process for multiplying printing surfaces. In this instance the cast is taken by the ordinary method of the precipitation of metals by electricity. To this art we shall again advert in another page. A variety of methods have also been practised for accomplishing the same purpose by the aid of a variety of materials, such as bituminous compounds, paper moulds, &c.

A variety of type and typographic processes of the most extensive and beautiful character was shown by the Austrian government at the Great Exhibition. The imperial printing press at Vienna was the source from which these excellent specimens of the printer's art were derived. This office is one of the most extensive in the world, and we subjoin a few particulars as to its operations. An engine of 20-horse power moves not less than 48 printing and 24 copperplate presses, and 10 glazing machines. There are, moreover, 36 large and 12 small iron hand-presses, 12 numbering and embossing machines, and 30 lithographic presses. A fresh supply of types is constantly supplied by 12 casting machines and 9 ovens, and 3,000 cwt. of type is kept on the premises. According to a moderate computation each cwt. contains about 40,000 types, and the 3,000 cwt. we mentioned make a total of 120,000,000 of types of various sizes and characters. 500,000 sheets, or 1,000 reams, of paper *per diem* are required for the consumption of the establishment. And all this is of comparatively recent growth, because we learn from the report of the Austrian Commissioners that only ten

years ago but 50 persons were employed in the Imperial Printing-office, that the type-foundry was small, and that there was but a limited lithographic staff attached to it, while at the time we write there are offices for letter-press printing, for copper-plate, lithographic, and chromolithographic printing, punch-cutting, type-founding, wood-cutting, book-binding, and for photography.

The objects which this extensive institution sent to the Great Exhibition were of the most various kind. Among them is a collection of 11,000 steel punches of characters and alphabets, of which we dare say that most of our readers have scarcely ever heard the name. There are, in fact, punches of 104 different alphabets, from the hieroglyphic, hieratic, and Demotic, down to the Kionsa, Laos, Shyan, Mandshah, and Formosan. There is a collection of gutta-percha and galvanized copper matrixes of wood-cuts, fac similes of a tique relievos; and, as a specimen of the typographic capabilities of this establishment, there is a copy of a certain work, entitled *The Hall of Languages*, and consisting of 17 sheets in elephant folio, containing the Lord's Prayer in 608 languages, printed with Roman letters, and in 200 languages in the characters peculiar to each language. This is a work of vast design and exquisite execution. A Japanese novel with all its wonderful characters was also printed at this establishment, and excited the greatest interest among those who are devoted to the study of languages.

Printing in different colours is an invention of comparatively very recent date, and may be said to be still in an undeveloped state. Formerly, when it was necessary to produce a coloured design, the outline was printed in neutral tint, and the rest finished by hand. But latterly great progress has been made in the application of a sort of mechanical artist, which takes the place of the human colourist, and prints the desired tint on the paper.

In most of these processes the colours are laid on in the following manner. The general design in some neutral colour is printed by one block of wood, then all the supplemental colours are printed on it one after another by blocks of wood, engraved only in those parts where they are to lay on the colour. In this way, by a series of printing operations, following one another, the different shades are laid on until the design appears fully tinted.

In this way the charmingly beautiful pictures of Mr. George Baxter, the inventor of oil-colour printing are produced. But in this case the outline of the design is engraved on steel plates, and the tints are afterwards filled in with softer metal or wood.

In copper-plate printing and lithography little machinery is necessary beyond the simple hand-press. It is generally known that the impressions conveyed by these processes are obtained in the one case by engraving as in wood engraving, and in the other by the assistance of a corrosive acid, which leaves the design untouched, but eats away the surrounding material so as to leave it slightly in relief. Chromo-lithography is the art of lithographing in colours, and is practised on similar principles to those above stated.

The compound plate-printing machine, invented by Mr. Wilks, at the suggestion of Sir William Congreve, was a beautiful and ingenious contrivance by which, at one impression, two or more colours were produced; and this machine is now used to produce the curious stamps used for patent medicines, and other Excise purposes. We are not acquainted with the precise arrangements of this machine.

CHAPTER V.

MANUFACTURING MACHINES — CONTINUED.

Section III.—Machines used for Construction.

Having in the preceding portions of this work reviewed the application of machinery, first, as a source of power, then as a source of motion, afterwards as engaged in industrial occupations upon textile substances, and lastly, upon paper and print, it is now our duty to consider it as applied to the more stern and obdurate materials used for industrial purposes; namely, metal and wood. A very little consideration will serve to show, that the construction of a machine intended to bring iron into shape, must differ very materially from one intended to deal with the soft and delicate fibre of silk or cotton. A far greater exercise of force is necessary for the former class of engine, and, as this cannot be associated with any complicated arrangement of working parts, the machinery employed for these more obdurate substances is necessarily very simple, and at the same time combines in itself great solidity and strength. Much mechanical ingenuity is however displayed in the structure of these engines, and they may very justly be considered as occupying a more important rank than the preceding, since it is by their instrumentality that other machines are made. Without the steam-hammer, the lathe, and the drill, such machines

as the printing press, the power-loom, and the carding-engine could not have been constructed.

Before entering upon our immediate topic, it may be interesting to the reader to know that the parts of many engines are often made by persons who devote themselves exclusively to that sort of work. Thus, in the watch manufacture, there exists a number of distinct trades, devoted to the production of different parts of the watch. The dial-plate is not made by the artificer of the balance-wheel, but by a person wholly occupied in that employment. It would appear that this subdivision of labour is attended with certain material benefits, for it is largely developed in the construction of much of our machinery.

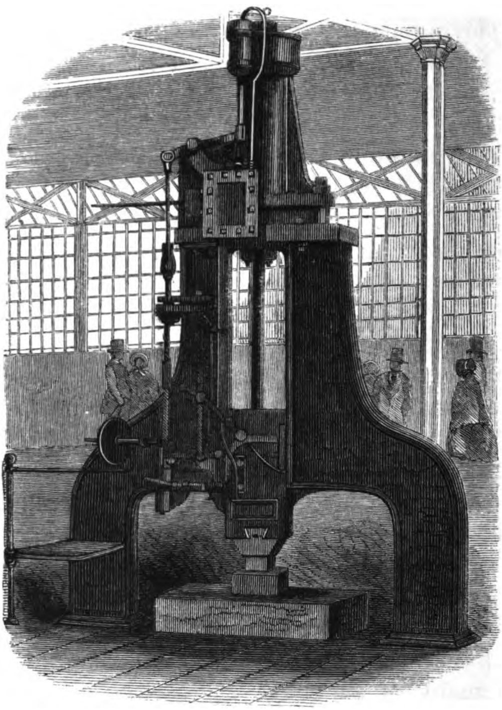
In all machines, it has been justly observed, there are certain parts which actually do the work for which the machine is constructed, the mechanism serving merely to produce the proper relative motion of those parts to the material upon which they operate, and these working parts being the tools with which the machine works. Accordingly, in machinery for spinning and its preparatory processes, for weaving of all kinds, and for paper-making, there are a variety of such working tools, as, for example, spindles and flyers, fluted rollers, heckles, and all the varieties of card-clothing, weavers' reels and shuttles, the wire-cloth used by paper-makers, &c., the making of each of which articles constitutes a distinct branch, and is carried on by a different set of workmen from those who make the machines. For the machine-makers usually purchase these parts from their proper makers, when they fit up their machines for sale. We have already noticed some of the ingenious machines used for making these working parts or tools of the machine—such as the card-setting engine, for making card-cloth for cotton, &c., and the automatic bobbin-making engine. There are also several very clever machines

for making the healds for weavers' looms, and we have seen a beautiful automaton engine in Manchester for making the dents employed in weaving. Generally, however, these parts of machines require manual labour trained up for this kind of work exclusively, and it is found that work of this kind is better and more economically done for the machine-fitter, than he could do it by employing his own men on such parts.

The machine first to be noticed is an excellent specimen of the class of constructing engines. It is a simple, grand, and powerful engine, capable of smiting a block of granite into powder, and as capable of breaking a nutshell without injury to the kernel. This machine is Nasmyth's steam hammer. Probably there is not on record an invention which has introduced itself into such extensive use in so short a time as this hammer. The patent was taken out in 1842, and in the course of nine years from that time not fewer than 380 of these wonderful instruments had been constructed, and were sent to different parts of the world. One of these was sent to the Exhibition of 1851, but, in consequence of a want of sufficient steam, and also by reason of the formidable concussions produced by the machine, it was not exhibited in action. The following notice of this hammer, which appeared in the "Illustrated London News," will be read with interest. The engraving which we have introduced to illustrate it was copied from a photograph taken in the Exhibition.

"In many of the large engineering establishments around London, we find three and four of these hammers are called into requisition; and we advise those of our London readers who have an opportunity of visiting any of the respective establishments of Messrs. Maudslay & Field, Lambeth (who have three hammers of the respective weights of 30, 15, and 5 cwt., for different kinds of work); Penn & Son, Greenwich; Blyth

& Co. and Seaward & Co., Limehouse; Miller & Ravenhill, Blackwall; and last, though most important of all, the highly interesting and extensive iron ship-building establishment of Messrs. J. C. Mare & Co., at the Orchard House, Blackwall, to lose no time in seeing the extraordinary operations performed through



the instrumentality of the steam-hammer, requiring for itself the attendance of one person only. The engraving represents an elevation of the hammer, which for this, the most useful size, weighs only 30 cwt.; but the most gigantic machine of the kind which has yet been turned out is that at Messrs. Mare's large works, having a ham-

mer of 6 tons weight, with a stroke of 6 feet. On a recent visit to this establishment, we found one of those ponderous and apparently unwieldy paddle-wheel shafts for a pair of marine engines, building by the celebrated firm of Maudslay & Field; this shaft, which had been entirely forged by the giant hammer 'Thor,' occupied upwards of three weeks from its commencement to its completion: it is of the extraordinary weight of 16½ tons, and 27 feet 9 inches in length; yet, by aid of a powerful crane, the operation of welding and forging this large mass is rendered as simple and easy as that of a horse-shoe in the hands of a country smith. Messrs. Mare & Co. have also three other Nasmyth hammers, each decreasing in power to suit various kinds of work. Referring to the hammer contributed to the World's Fair, we find the anvil, which is chiefly buried below the floor, weighs 8 tons; the hammer itself, already mentioned, and which is suspended from the piston rod, 1½ ton: the piston which works in the cylinder, placed at top of the machine, is of 16 inches diameter, and the extreme fall of the hammer, or what in steam-engines is usually called the stroke, is equal to 42 inches. The ingress steam pipe is of 2 inches diameter, the pressure of steam usually employed being equal to 40 lb. on the square inch.

"The hammer being on the self-acting principle, every degree of blow, from that of merely cracking an egg-shell to that of a dead pressure of 500 tons, is attainable. The whole width of the frame at the level of the floor is 11 feet; and the space between the legs in which the top of the anvil is placed is 7 feet; the height of the machine being about 15 feet. The frame is bolted down to large iron plates let in flush with the floor; but it the hammer at the Exhibition had been intended to have been shown in operation, a much stronger foundation would have been required. By admitting the steam

under the piston, the hammer is elevated to the desired height; and by its own gravity the hammer falls: but the fall may be instantly eased, if desirable, by the admission of steam, according to the particular kind of blow required. In ordinary work, as many as 70 blows are given in a minute.

"In the former part of this notice we mentioned the large engineering establishments in and around the metropolis, at which the steam hammer may daily be seen fulfilling its appointed duties; but at all the principal anchor-makers, at all the large engine-builders, and at the principal railway manufacturing establishments in the kingdom, the making up of iron, either from scraps, old rails, hoops, or from the pile, is also effected by means of the Nasmyth hammer."

From a statement of iron made by the use of this machine at the North-Western Company's manufacturing establishment at Crewe, in six months ending June 1851, we find that upwards of 176 tons of iron, in the shape of tires, axles, &c., including a shaft for a stationary engine, was made; and that, after deducting the cost of wages, scrap iron, and coals, there is a clear profit of upwards of 2,300*l.* Nothing can be more convincing of the utility of this engine than the above fact. Before the introduction of this adjunct to the smithy, the forging of the large marine engine shafts was not only a tedious but an uncertain process; and many an accident which has occurred to the ocean steamers might have been traced to the imperfect forging of the iron; for, without blows of sufficient energy, it is impossible to expel the scoria from between the bundles of iron rods, which, as in the United States, they attempted to weld together to form their main shafts.

The beautiful anchors forming part of the Great Industrial Show, which were placed in the yard at the west end of the Exhibition building—all were wrought

by the aid of the steam-hammer, and were severally contributed by Brown, Lennox & Co.; the Bedlington Company, near North Shields; and Fox, Henderson & Co., the constructors of the Palace of Glass, for Captain Rodgers, who has designed a new form of anchor.

It is difficult to say to what other uses Nasmyth's last invention will hereafter be applied. At the present time, however, in addition to the formidable kind of work for which it has hitherto chiefly been employed, its application to the stamping out of dish-covers, and the moulding and forming of silver plate, is now in progress.

It will be observed that the essential principles upon which this powerful and beautiful engine is constructed are very simple. A ponderous hammer-head is dragged up by the piston-rod of a steam-engine, and then suddenly discharged. It seems remarkable that this application of steam should not have been invented at an earlier period, for it is evident that the far-sighted James Watt had contemplated the possibility of it, and in the specification of his patent, taken out in April 1784, alludes to a probable mode of applying the piston-rod of a steam-engine, in connexion with a heavy hammer or stamper, for forging iron and other metals.

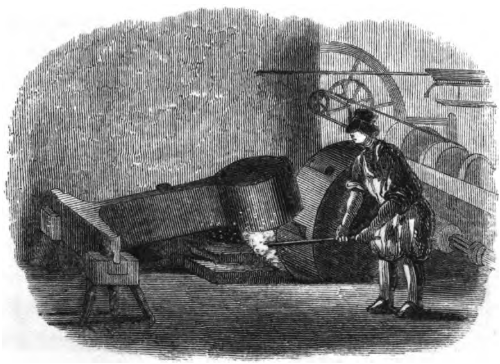
A still more powerful hammer than any yet described was constructed for some iron-works at Dowlais. The hammer of this engine is upwards of 6 tons in weight, with a clear fall of 7 feet perpendicular. The force of the blow which it gives out is tremendous; but is under such control as to be made to drive a nail into soft wood, with a succession of the most delicate taps. This monster hammer has been constructed for giving some six or eight tremendous blows to the masses of iron called "blooms," from which the railway bars are rolled, so as thoroughly to weld them into one solid

mass, before they are drawn out. It is remarkable to see the effect of this immense machine in driving out every particle of cinder from the iron, and thus thoroughly welding and incorporating the whole mass together. The anvil of this monster steam-hammer has been supposed to be the largest casting in the world, being no less than 36 tons, in one solid mass!

This invention has also been applied for the purpose of driving piles, with great success. One of the Nasmyth hammers, fitted up at Devonport, drove a pile 15 feet into the ground in 17 seconds. The whole of the operations required to be performed on each pile, from the time it is floated along-side of the stage until it is imbedded in the solid foundation, was only 4½ minutes. The great stage, carrying the machine, boiler, workmen, and everything necessary, was made to run along its railway like a wheel-barrow. It picks up the pile out of the water, hoists it high in the air, drops it into its exact place, then covers it with an iron cap, which follows it as it sinks into the ground, then thump goes the monkey on its head, jumping at the rate of 70 jumps in a minute. At the first stroke the pile sank 6 feet. The head of the pile is, also, not nearly so much injured, by this mode of driving, as by the ordinary method of dropping a monkey from a great height upon it.

Ordinarily the instrument used for forging is what is called a tilt-hammer. The accompanying cut represents this formidable-looking object. Its construction is very simple; it is merely a heavy mass of metal, weighing from 3 to 4 tons, the head of which is placed over the anvil, which is sunk in the ground, while the shank rests upon pivots, in a strong frame. In order to lift this hammer, and so call into exercise the force of its gravity, a large wheel is arranged near the head, upon the circumference of which projecting pieces or cogs are

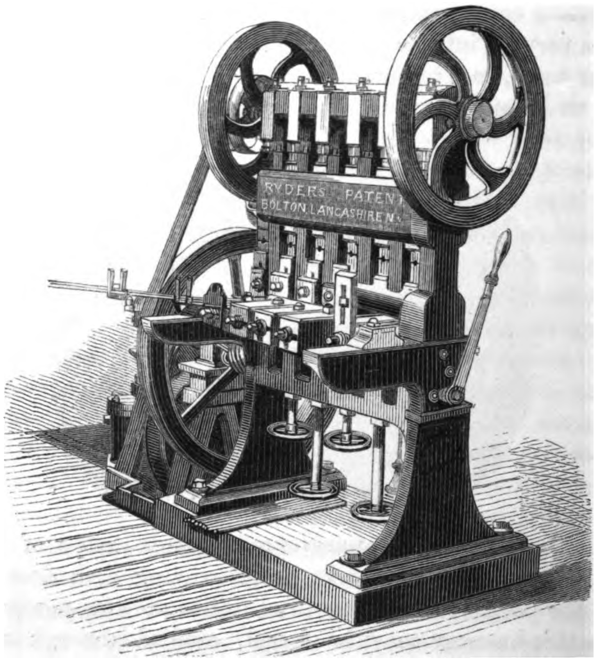
placed. As this wheel revolves, the cogs catch one after another under the head of the hammer, lift it up a certain distance, and then release it, when it falls with all its weight upon the object placed on the anvil. The force of this hammer, therefore, is merely that which is acquired by its own weight, to which is superadded the impetus of its fall. But the height to which such a hammer can be raised is very limited, and in real power it is very far inferior to the Nasmyth hammer. The cut represents, in a picturesque manner, the welding of iron at an intense heat by this machine—an operation of



singularly beautiful appearance, in consequence of the brilliant shower of sparks accompanying each descent of the ponderous hammer-head. The moving power of the tilt-hammer may be steam, applied through the medium of pulleys and shafting, or it may be water-power from a water-wheel, used in the same way.

Another very interesting and ingenious machine, used for forging iron, but on a much smaller scale than the forge-instruments just noticed, is Ryder's Patent Forging Machine. This engine is shown in the cut, p. 230, from a photograph, and was exhibited in action at the Great Exhibition. It was not possible to use iron in a heated

state in the Exhibition, and the operation of the machine was consequently exhibited by bars of lead, which were fashioned by it with surprising ease and velocity. It was worked by an oscillating engine, having a 7-inch cylinder and 9-inch stroke: a horizontal shaft, which was caused to rotate by means of the crank, carried on



it a metal pulley of 16 inches diameter, from which a band passed, when in ordinary use, to drive a fan of 17 inches diameter, for the forge fire. The fly-wheel was on the same shaft, a band from which passed to a 12-inch driving-pulley, running on a second shaft, by which five eccentrics were worked, and by which as many hammers were caused to fall at proper intervals,

each of which was again lifted up by a spring: this operation was repeated 700 times in a minute. Under each hammer was an anvil, furnished with flat and other dies, on which the steel or iron to be operated on was placed—being kept in its proper position by a rest in front of each. The dies may be raised or lowered at pleasure, by means of vertical screws turned by circular open handles. The whole was mounted in a strong frame, and, by means of bolts passing through the iron base-plate, was firmly secured to the joists of the floor.

This machine was chiefly used for forging mule and throstle spindles for cotton machinery, screw-bolts, round, half-round, square, flat, and three-square files. But it is also applicable to a variety of other uses, and forms a most convenient, powerful, and useful instrument for the purposes of the iron or metal worker, owing to the high velocity at which the machine runs, and the powerful stroke given by it to the metal which it forges; it requires to be very strongly braced and secured, and even then its concussions and vibrations become very perceptible. It was remarkable to notice how rapidly a rod of metal was tapered down by it into one of much smaller diameter, or was formed into a flat or angular bar.

From the forging machines of various application, we may now pass on to another kind of instrument of somewhat analogous use,—namely, the riveting machine. In both these engines, iron in the heated state is the material commonly operated upon; and the treatment it receives, namely, that of compression, is in both cases similar, but the object intended to be accomplished of course differs in each. The forging engine reduces the metal into form, and moulds it at the will of the worker; but the riveting engine simply crushes up a red-hot bolt, and so clasps two iron plates inseparably together.

The first application of machinery to riveting iron plates was introduced by Mr. Fairbairn of Manchester. The following is Mr. Fairbairn's account of his invention:—

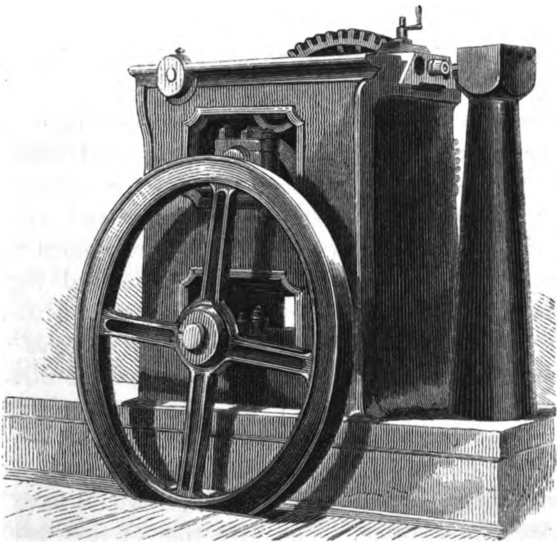
"The invention of the riveting machine originated in a turn-out of the boiler-makers in the employ of this firm about fifteen years ago. On that occasion the attempt was made to rivet two plates together by compressing the red-hot rivets in the ordinary punching-press. The success of this experiment immediately led to the construction of the original machine, in which the movable die was forced upon the rivet by a powerful lever, acted upon by a cam. A short experience proved the original machine inadequate to the numerous requirements of the boiler-maker's trade, and the present form was therefore adopted about eight years since."

The large stem is made of malleable iron, and having an iron strap screwed round the base, it renders the whole perfectly safe in the case of the dies coming in contact with a cold rivet, or any other hard substance, during the process. Its construction also allows the workman to rivet angle iron along the edges, and to finish the corners of boilers, tanks, and cisterns; and the stem being 4 feet 6 inches high, it renders the machine more extensive in its application, and allows of its riveting the fire-box of a locomotive boiler, or any other work within the given depth.

In addition to these parts, it has a broad moving slide, in which are three dies corresponding with others in the wrought-iron stem. By using the centre die, every description of flat and circular work can be riveted, and by selecting those on the sides it will rivet the corners, and thus complete vessels of almost every shape. This machine is in a portable form, and can be moved on rails, with care, to suit the article suspended from the shears.

The introduction of a knee-joint gives to the dies a variable motion, and causes the greatest force to be exerted at the proper time, viz. at the closing of the joint, and the finishing the head of the rivet.

In other respects the machine operates as before, effecting by an almost instantaneous pressure what is performed in the ordinary mode by a long series of impacts. The machine fixes in the firmest manner, and



completes eight rivets of ¾-inch diameter in a minute, with the attendance of two men and two boys to the plates and rivets; whereas the average work that can be done by two riveters, with one "holder on," and a boy, is 40 ¾-inch rivets per hour; the quantity done in the two cases being in the proportion of 40 to 480, or as 1 to 12, exclusive of the saving of one man's labour. The cylinder of an ordinary locomotive-engine boiler, 8 feet 6 inches long, and 3 feet diameter, can be riveted

and the plates fitted completely by the machine in four hours; whilst to execute the same work by hand would require, with an extra man, twenty hours. The work produced by the machine is likewise of a superior kind to that made in the ordinary manner, the rivets being found stronger, and the boilers more free from leakage, and more perfect in every respect. The riveting is done without noise, and thus the constant deafening clamour of the boiler-maker's hammer is almost entirely removed.

This valuable addition to mechanists has been very extensively employed, and has proved itself of signal service, as an auxiliary instrument in the department of labour for which it is adapted. It was used with complete success to rivet together the plates comprising the tubes of the great bridges at Conway and over the Menai Straits. And by its use these enormous masses of metal plate have been securely fastened together without noise. It need scarcely be mentioned that the object of introducing the rivets into these holes while red-hot is to secure the subsequent powerful contraction of the metal in cooling, by which the plates are bound together with the most powerful force. It may be safely stated, in fact, that but for this machine the construction of the tubular iron bridges would have been almost impracticable. The invention of this machine, like that of several others used in manufactures, as the result of a "turn-out" on the part of the operatives, only gives additional testimony to the folly of such proceedings, and may serve to show that the usual consequences of a "strike" are much more formidable to the misguided persons who originate it than to those who employ them. Mr. Fairbairn's machine was shown at the Great Exhibition, and the cut which illustrates it was taken from a photograph of the object itself.

Another very ingenious and powerful riveting engine

of recent introduction deserves our attention, and is interesting as affording an example of the direct application of the expansive force of steam. This machine was invented by Mr. Garforth of Manchester. In this engine the force for driving up the rivet is entirely obtained from the thrust of a piston-rod, impelled forward by high-pressure steam. The mechanism is as simple as possible. There is a powerful cast-iron frame, in the centre of which is a steam-cylinder, with piston and rod, placed horizontally. Steam can be let in or out of this cylinder by a lever governed by the workman. At the end of the piston-rod is placed the die for pressing up the rivet, and the stem of wrought-iron carries the opposing die, as in the former engine. The object to be riveted is placed between the piston-rod and the stem, the steam is then admitted below the piston, and by its expansive force drives the rod forward, and squeezes together with resistless energy the plate and the rivet.

In this apparatus, the extreme simplicity and beauty of the principle of which should command our admiration, it is considered that the elasticity of the steam offers an admirable security against any injury from the accidental introduction of a cold rivet, or from any irregularity in the thickness of the plates. It is also an advantage that it can be set in motion just when the workman is ready, instead of his being obliged to be ready at the exact moment when the cam acts on the knuckle in the other machine. This engine is capable of putting in 360 rivets per hour, with the attendance of one man and three boys. With the machine at the Exhibition were shown two pieces of boiler-plate riveted together by it, and planed through the centre of the rivet to exhibit the extreme accuracy of the work effected by it. It is a disadvantage, however, that this machine is necessarily stationary, whereas the other is extremely portable, and can be consequently applied to

work at a distance from the manufactory, by carrying a long strap to its working pulley.

The punching engine is constructed on principles somewhat analogous to Fairbairn's riveting machine, and its operation bears some resemblance to that of the latter engine, only that in the latter instance the pressure of the die is counterpoised by the resistance of the opposing die, while in the punching machine it is unresisted, and is carried on until it has penetrated the metal. We shall briefly describe this engine, an excellent representation of which will be found in the former volume on the Great Exhibition. The machine consists of a powerful cast-iron frame, at one side of which is a recess, at the entrance of which the punch works perpendicularly. The punch is a solid plug of steel, set in a movable frame. This frame receives a slow but extremely powerful up-and-down movement from a shaft contained within the machine, and driven by cog-wheels. Motion is given to the apparatus by a strap, and a heavy fly-wheel gives the requisite momentum for driving the punch through the metal. The plate to be perforated is laid on the edge of the recess spoken of, over a hole in the bed on which it rests; the machine is set in motion and the punch slowly descends, and passes clean through the metal with as much apparent ease as though it were a sheet of pasteboard. A circular piece of iron is thrust out, and the punch rises to repeat its perforation on the next spot presented to it. Very great heat is extricated in this process from the development of that latent in the metal by the severe pressure to which it is subjected. By an ingenious arrangement of machinery, the punching machines in Woolwich Dockyard are rendered quite self-acting, and the plate is presented to the punch upon a movable wagon, which advances it with the greatest precision exactly to the requisite distance for the succeeding hole, until the task

is completed. The pressure necessary to penetrate an iron plate .08 of an inch in thickness by a punch half an inch in diameter, requires a power of 6,025 pounds, and through one of .24 inch in thickness it demands a force of 17,100 pounds.

The shearing engine is generally connected with the punching machine, and is placed at the opposite side to the punch, or above it, as may be most convenient. The shearing portion is a flat bar of steel, brought to a cutting edge, and acting against a similar edge on the bed of the recess, somewhat like a pair of scissors. Its movement is effected precisely in the same way as that of the punch, and is equally powerful of its kind.

It is a wonderful spectacle, illustrative of the power of human genius over the obduracy of inert masses of metal, to enter one of the large machine-shops of Manchester, and to behold a row of these monster engines at work. To hear the clanging of the metal as hole after hole is made in it; to see it cut like a sheet of paper, and shaped into its required figure; and to feel the solid ground trembling under the effects of these cyclopean instruments, constitutes a realization of the triumphs of mechanism not easily to be erased from the mind. The punching and the shearing engine are to the machine-maker what the scissors is to the tailor, and the auger to the carpenter. They are the rudimentary constructing instruments, and are among the most indispensable furniture of the iron-factory.

The American engineers have invented a punching and shearing apparatus, in which great power is obtained with a very small amount of friction. These machines were shown at the Exhibition, and excited much attention by their great simplicity and power. The apparatus consisted essentially of an ingenious arrangement of cams or eccentrics, and levers, by which scarcely any friction was produced, and a most severe degree of pres-

sure attained. This instrument is used either as a powerful press for packing compressible goods, or, as just noticed, for punching and shearing sheet-iron.

Before now passing on to the consideration of a more refined class of machines used in constructing other machines, it may be useful to make the following general remarks upon the application of self-acting machinery for this purpose. The almost mathematical accuracy and precision with which the forms of the various details, whether of the most delicate, or most ponderous machines are executed, is highly deserving of notice. To produce pieces of machinery so perfect by manual dexterity and labour were hardly possible; and if possible, would entail so great an expense, that neither in quantity nor price could we by any increase of machinery and skilled population have kept pace with the demand which has followed upon the increased per- ection and facilities of production realized by improved mechanism.

Only sixty years ago, nearly ever part of a machine had to be made and finished to its required form by mere manual labour; that is, we were entirely dependent on the dexterity of the hand and the correctness of the eye of the workman, for accuracy and precision in the execution of the parts of machinery. With the advances of the mechanical processes of manufacture invented by Watt, Arkwright, Compton, Brunel, Didot, and Jacquard, a sudden demand for machinery of unwonted accuracy arose, while the number of skilled workmen then existing were neither sufficiently numerous nor skilful to meet the wants of the times. Mr. Henry Maudslay, about forty years ago, introduced the *slide principle* into the tools and machines employed in the production of machinery; and, but for the introduction of this principle, we never could have attained to the advanced stage in machine-making in

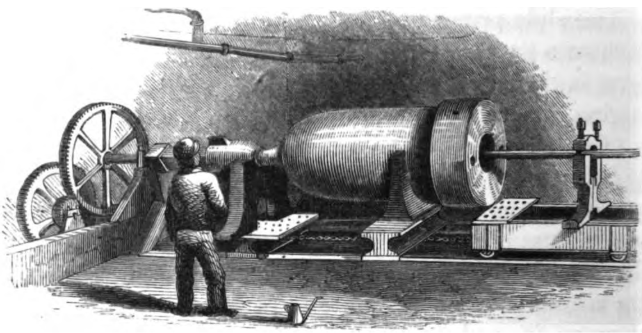
which we now are. The principle here alluded to is embodied in a mechanical contrivance which has been substituted for the human hand for holding, applying, and directing the motion of a cutting-tool to the surface of the work to be cut, by which we are enabled to constrain the edge of the tool to move along or across the surface of the object, with such absolute precision, that with almost no expenditure of muscular exertion, a workman is enabled to produce any of the elementary geometrical forms—lines, planes, circles, cylinders, cones, and spheres—with a degree of ease, accuracy, and rapidity, that no amount of experience could have imparted to the hand of the most expert workman.

The slide principle is embodied in the slide-rest, now become a part of every lathe, and applied in a modified form in the boring mill, the planing machine, the slotting engine, the drilling machine, &c. &c.

Simple and outwardly unimportant as this appendage to lathes may appear, it is not, we believe, averring too much to state, that its influence in improving and extending the use of machinery has been as great as that produced by Watt's improvements of the steam-engine itself. Its introduction went at once to perfect all machinery, to cheapen it, and to stimulate invention and improvement. It is in fact quite certain that the facility of executing and fitting precisely the parts of machines, has rapidly effected an improved construction of them, and a more precise adaptation of machines to the functions they have to perform. Soon after its introduction the slide-rest was made self-acting, that is, its motion along or across the surface to which the tool it held was applied were rendered independent of the attention of the workman in charge of it.

The first engine to be noticed is the boring engine, by which the cylinders of steam-engines are cut out and smoothed on the inside. The great machine represented

in the cut as employed in boring the cylinder of the hydraulic press which raised the tubular bridges, furnishes a good specimen of this kind of apparatus. In these machines, the cylinder to be bored is firmly secured upon a frame prepared to receive it, and the cutting instruments are gradually advanced by a screw into its interior: the cutting tools revolve as they enter, and remove portions of the metal gradually downwards until the whole cylinder is bored. In the best arrangement of these machines the advance of the boring tool is entirely automatic. The form assumed by this engine differs in different cases with the nature of the work it



has to fulfil. But the boring machine may be in general terms accurately described as a contrivance for working a bore or tool, which, by a rotary motion on its axis, cuts out a hollow cylinder in any substance it is applied to. The cylinders of steam-engines and those of hydraulic-presses require to be bored with extreme accuracy and care, since any inequality in the diameter of the cylinder would certainly cause great leakage when a high pressure was applied to the piston working in it. It is only by the aid of this engine that our invaluable prime movers are obtained; for it may be safely stated, that the manufacture of a steam-engine of any working

dimensions could not be accomplished without the assistance of the boring engine. It is also applied for other machines, such as pumps, &c.

The lathe is a machine of the most extensive use, and absolute necessity to the manufacturer. Scarcely any part of a machine exists to which the use of the lathe has not been in some way or other necessary. The holes even of the cast-iron framing are often cut by a lathe, and the bolts are turned and screwed also by its means. It is an instrument of universal value, and of the first importance in practical mechanics. This machine consists essentially of the following parts. There is first, a horizontal bed, formed of two parallel bars of wood or metal firmly united together. Upon this bed are fixed two portions, called puppets; the one of these is fixed, and carries the pulley or mandril, or horizontal axis by which rotation is communicated to the work to be turned; while the other is capable of moving to and fro along the bed of the lathe, and so adapting itself to the length of the object about to be operated upon. In addition to this there is what is called the rest, a bar of iron upon which the cutting tool is placed, and this is also capable of being moved along the bed of the lathe, and also nearer or farther from the work on the lathe. This constitutes the upper part of the lathe, and these parts are supported upon a strong framing, either of wood or iron. In order to produce a rotary motion, an axis with a crank is placed underneath, and by means of a treddle this axis is made to revolve by the pressure of the foot of the workman. This axis carries at one end a fly-wheel, the edge of which is grooved so as to carry a band, and by taking this band over the pulley at one end of the lathe the movement is communicated to it and to the work attached to it. Such is the essential construction of a simple foot-lathe, and if it be well understood it is not then difficult to

comprehend the arrangements of the more complicated and powerful engines used in manufactories.

In lathes driven by the steam-engine, and intended to produce a larger kind of work than can be obtained from the foot-lathes, the general principles of construction remain the same. There is the head-stock, with its pulley and axis, to which are fitted arrangements for attaching the work to be turned. There is the bed of the lathe, and the end opposite to the head-stock, carrying the back centre with its various adjustments, and there is also the rest for the tools. The only part absent is the axle and fly-wheel, for this part is not here necessary, since the rotary motion is communicated from a shaft by means of a band, and this shaft is actuated by the steam-engine. In heavy work, however, and indeed in all power-lathes of any value, the self-acting principle is introduced, and the following adjustments are made to accomplish that object. The work is necessarily fixed by being secured to the mandril of the head-stock end, and revolving on the pivot at the back centre, and motion is given to it by the pulley. The cutting-tool is fixed in the rest by screws, and the rest itself is made to slide from one end of the work to the other by a movement from below. In this way the work is gradually cut from one extremity to its opposite. By means of a screw acting in a direction across the bed of the lathe, the tool can be advanced or withdrawn from the work, and thus it can be cut to a greater or less depth. The tools are mostly of very simple forms,—generally flat, like a chisel, or pointed and wedge-shaped. To those unaccustomed to see such powerful engines, it will appear a surprising spectacle to observe the apparent ease with which great shavings of iron are removed in the power-lathe. Frequently long pieces of metal, in spiral form, curl off from the edge of the tool. Water is commonly used to facilitate the action of the tool, and is often converted

into steam as it drops upon the heated surface. The use of the lathe in manufacturing work is necessarily confined, as a general rule, to the production of cylindrical bodies, or for giving a round form to particular parts of machines, such as in shafting at the parts where the shaft is carried by the brass bearings.

But the lathe is capable of performing the most wonderful kind of work, and there are few, if any, geometrical figures which cannot be cut by it. For this kind of work, however, a very peculiar arrangement of the head-stock of the lathe is necessary; and it is chiefly for the pursuits of the amateur, or for the objects of the engraver, that this kind of machine is made. It would be difficult, if not impossible, to describe the modification of apparatus necessary for the production of work of this kind. The general principle may be expressed thus:—that instead of a continuous circular movement being given to the work which is turned, it is made to receive a variable motion, determined by certain wheels in connexion with the pulley and mandril. The work is thus made to present itself in a variable manner to the cutting-tool, and, consequently, does not receive a regular cylindrical figure, but some other, such as that of a rose, an oval, &c. These lathes are often called rose engines, from the beautiful manner in which they are capable of cutting out a figure of that shape. They are employed to produce the kind of engraving called engine turning, employed for ornamenting the back of gold and silver watches, snuff-boxes, and similar objects. For the massive objects of the machine-shop these philosophical instruments—for such they may very properly be termed—are wholly out of place, as much so as the balance of the chemist in the ware-room of the iron dealer. The work they produce is, however, of the most exquisite description, and if unfit for the useful arts, it often deserves to take rank among the fine arts.

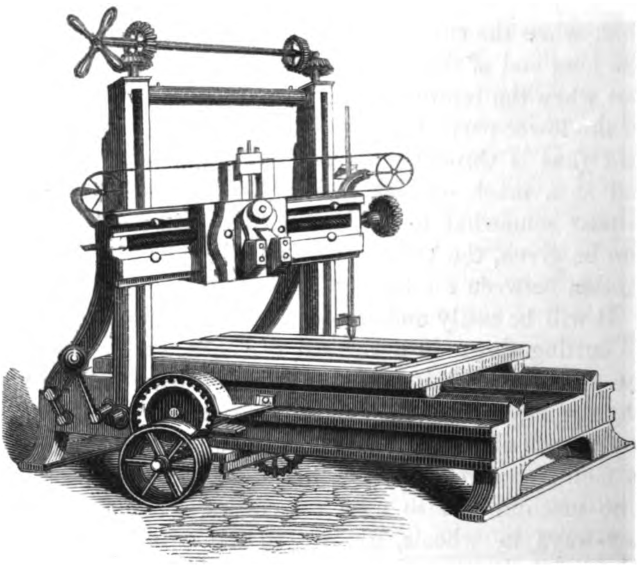
A machine of equal value with the lathe, but of much more modern introduction, is the shaping machine—a name very appropriately given, and descriptive of the performance of this engine. It is also sometimes called a slotting engine. One of the most perfect and beautiful engines of this kind was exhibited in 1851, by Mr. Whitworth, of Manchester. The principle on which this engine works is simply that of a vertical chisel, moving up and down, and cutting through the metal as it descends. A massive cast-iron framing, carrying an axle in the middle, which revolves by pulleys and a band, supports the parts connected with the movement of the chisel above, and below is the bed on which the work to be shaped is placed. Motion is given to the chisel by a crank, which is actuated from the axle referred to. The work is placed beneath, and the chisel slowly descends, cutting down a paring off it. By an ingenious arrangement of cogs the bed is capable of being moved in concert with the rest of the machine, and thus continually presents a fresh surface for the tool to act against. The relative adjustment of these parts is of course carefully arranged, and it is a most interesting sight to observe these iron workmen chiselling their obdurate work into shape, without any sort of human assistance. Mr. Whitworth has introduced into this machine, and others, a very singular and interesting movement. In all machines for cutting metals it is found necessary to make the motion of the cutting-tool very slow, otherwise, on coming in contact with the metal, it would be apt to be broken. This, however, involves of course a loss of time, and it is of importance, as far as possible, to obviate such a loss. It might seem as if this were impossible, unless the tool could be made to move slowly as it was cutting, and could then return back very quickly, and thus save time in the return. To any

person conversant with mechanics, such a movement in machinery will appear very difficult of accomplishment. It has, however, been admirably effected by Mr. Whitworth, and in a very simple manner. The crank-pin, by which the cutting-tool is set in motion, is made to work in a hinged lever with a joint below, so arranged that, when the cut is being made, the pin is working in the long end of the lever, and thus made to move slowly, but when the return motion is made, the pin is working in the lower part of the lever, much nearer the hinge, and thus is throwing the top end and the connecting-rod at a much greater rate. This explanation may appear somewhat unintelligible, but it is the best that can be given, the principle being this—the difference of motion between the long and the short end of a lever.

It will be easily understood that any machine capable of cutting down in a vertical direction, can be applied for giving a definite form to a block of metal. Any angular figure can be produced by this engine under the control of the workman, in whose hands it becomes, in fact, a powerful knife, cutting out just as he sees fit. The machine is also used for cutting what are called key-ways in wheels, grooves in the axle-hole of the wheel for the reception of wedges of iron intended to hold the wheel part to the axle. The use of this machine may be understood if the reader will suppose it to be necessary to cut a square hole through a mass of iron. This machine drives the cutting-tool down through a round hole, which is made to start with, and, by a succession of plunges, hews away the sides until a regular square has been formed. The purposes, in short, to which it can be applied, are endless, and it therefore justly holds a conspicuous place in the machine-shop.

The planing machine may be said to represent an iron carpenter, for all that the latter effects upon wood with his planes, this machine accomplishes by means of its tools,

(see cut). It is a beautiful and wonder-exciting engine, whether we regard the precision of its work, or the power with which it accomplishes it. It differs from the shaping-machine in this important respect, that the work is cut by being carried against a stationary cutting-tool. The



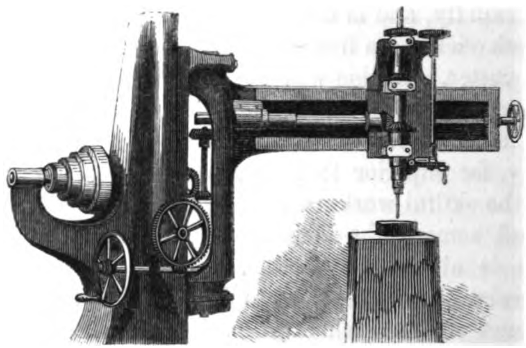
tool is, it is true, capable of lateral and of vertical movement, but this is merely so as to present it to a fresh part of the work, as in the slide-rest of the lathe. The object intended to be planed, is firmly secured to the bed of the machine, and this being capable of a to-and-fro motion, is set going. A cutting-tool is arranged in a strong frame placed across the length of the engine, and the carrying forward of the bed of the machine with the work on it, brings the latter in contact with the tool, which planes, or rather ploughs along its surface, scraping up a shaving of iron as the work passes beneath it.

In some engines, called curiously enough "Jim Crow machines," the cutting-tool "turns about" when the work has passed beneath it, and begins to cut it again as it returns. In many, however, the planing is only accomplished one way, and the bed or table is made to return rapidly, and is then again slowly carried forward, the work yielding a fresh tribute of metal to the power of the cutter. In this way the most accurate plane surfaces may be produced, for the machine is incapable of giving out incorrect work, and these surfaces are, consequently, far superior to those obtained formerly by the file of the skilful workman. For, in the best work done by hand, some slight deviation from absolute rectilinear motion is always observable. The planing-machine may truly be said largely to have contributed to the excellence of our mechanical manufactures.

The drilling machine, of which a good specimen is figured in the cut, is an engine of simple construction, but of very great practical value. It might be said to represent a vertical lathe, with this exception, however, that the work is stationary, while the tool revolves. It will be seen by the cut that this machine contains an arrangement for giving rotary motion to a drill, and by means of screws connected with the arm, this drill can be moved backwards or forwards, and also in a vertical direction. This machine is used for drilling the end-plates of the tubular boilers of locomotives, and for other work. All holes within the range of the machine can be drilled without removing the work till finished. It is also adapted for work of a massive character, such as large cylinders, &c., which could not be conveniently lifted and placed on the table of the ordinary vertical drilling machine. The latter engine was much used in the construction of the Exhibition building, and is represented in the first part of this work.

Among the most beautiful of Mr. Whitworth's

machines was that which was called the measuring machine. Two of these measuring machines were exhibited, one of them adapted to measuring to the ten-thousandth of an inch, and the other to the millionth



of an inch. They are both based on the principle of micrometer wheels, mounted on screws of fine and accurate pitch. The instrument consists of a massive iron frame, or bed, about four feet in length, along the upper surface of which is a right-angled "V" groove, in which is laid a square steel standard bar, one yard long. One end of the bar rests against a fixed point placed opposite its centre; another short square bar, resting in a continuation of the same groove, is brought into contact with the other end of the standard bar, by means of a screw having a very delicate adjustment. This screw has ten threads in an inch, and to its head a wheel is attached, having 400 teeth; consequently, if the wheel is advanced one tooth, the short bar is moved through the 1-4000th of an inch. An endless screw, having a single thread, is in gear with this wheel, and carries a wheel or plate, the circumference of which is divided into 250 equal parts. As an entire revolution of the endless screw will advance the first wheel one tooth, it is clear that, if the

plate is moved one division, the corresponding movement of the short bar will be the millionth part of an inch. This almost inconceivably minute space is rendered perceptible by interposing a small piece of steel, about 1-10th of an inch thick, called the contact piece, between the opposed ends of the square bars; if the distance between these exceeds the thickness of the contact piece by the millionth of an inch, it will drop between them by its own gravity, but an advance of one division of the plate will suffice to retain it. The contact piece will also be held by the expansion of the long bar, if the warm finger be laid on it for a single instant.

The chief practical applications of these very accurate means of measurement are—first, in the determination of the errors of standard measuring-rods; and secondly, in the manufacture of hollow and solid cylindrical gauges, made with a view of establishing uniformity in the size of rods, tubes, taps, dies, and other materials and tools used in the construction of machinery. The general adoption of them would enable our manufacturers to replace the worn or damaged parts of a machine in any quarter of the globe, with a perfect confidence that each new part would fit those previously constructed.

In addition to the machines now described, there are several minor forms used in all large machine-shops, and adapted for different kinds of work. Those, however, here enumerated, are the best and chief representatives of the engines used in the construction of other machines, and, as such, they will be regarded with all the interest which necessarily attaches to them. These are machines chiefly of the present century, and they exhibit, in a wonderful degree, the power and genius of the machinists of our country.

The machinery used for wood-work is not less ingenious than that employed for reducing iron to shape,

but is necessarily very different in its character and construction. It is chiefly of American origin. In that country machinery for working in wood is even more largely employed than with us, and these machines find their way into workshops of a smaller character. The much greater value of manual labour in that country, it has been justly remarked, is exhibited by the fact that as little work as possible is done by hand; and that more attention is paid to economy of time and labour, and to the production of rapid results with the least possible expenditure, than to great durability and finish. Where many natural obstacles are to be contended with by a scattered population, we must not look so much for elegance of workmanship as for boldness of design. The machinery used in the construction of the wood-work of the Exhibition building was entirely of this character; and without its assistance the completion of that wonderful work in any reasonable period would have been wholly impracticable. And such machinery is very generally applicable to the preparation of wood-work for ordinary buildings, and is coming rapidly into use for such purposes. Since, however, some pains were taken to give a minute description of these machines in Chapter VI. of the first part of this work, it is unnecessary here to reconsider this subject.

CHAPTER VI.

MANUFACTURING MACHINES—CONTINUED.

SECTION IV.—MACHINERY USED IN THE ARTS.

IN discussing so extensive a subject as that contemplated by the title of the present chapter, it is obvious that some principle of selection must be adopted, since a volume of great size would be necessary to treat of all the machines used in the arts. Following, however, the classification adopted in the Great Exhibition, we shall occupy the pages of this part of our work with a notice of some of the most remarkable machines connected with Class 6. Our first business will be with those engines used for operating upon water, either in the form of pumps, water rams, &c., or in that of machines used for the extraction of water. And these are among the most universally required engines, since water constitutes one of the prime necessaries of almost all manufactures.

Pumps certainly attracted much notice at the Great Exhibition, and their performance was the subject of much speculation and of high interest. The ordinary form of this machine is very familiarly known, and need not be described. It consists of a piston and cylinder with appropriate valves, and acts by lifting up the water as

one would lift it by a cup or a bucket. But many contrivances have been adopted with a view of doing away with the pump-piston and of obtaining a continuous instead of an interrupted stream of water. For low lifts these have been more or less successful, but for lifts of greater height they have generally failed; and the piston and cylinder has been found to be the best form of apparatus for that purpose.

Let us here notice the immense importance of these engines by a reference to the vast work which they were recently called upon to execute at the Lake of Haarlem. In the sixteenth century there were a number of small lakes covering a large portion of the province of South Holland, between the towns of Amsterdam, Haarlem and Leyden. Four of these lakes lying contiguous to each other, covered an area of about 15,000 acres; and in process of time, the soft alluvial soil separating them gave way, and the four lakes became merged into one. The large lake thus created became continually larger, and absorbed more of the surrounding country, until at length, at the commencement of the last century, the waters extended over an area of 45,000 acres, with an average depth of 13 feet below low water in the Zuyder Zee. This lake constitutes what is now called the Lake of Haarlem. Considerable public alarm was excited by the rapid extension of the boundaries of this lake, and the people of Holland determined to make a bold effort to arrest its progress. At an expense of about 33,000*l.* they erected works of defence, which for a time checked its increase; and an annual cost of nearly 4,000*l.* was incurred in sustaining these works in good order.

In November, 1836, a furious hurricane drove the waters of the lake upon the city of Amsterdam, and immerged upwards of 10,000 acres of low land. In the month of December following, another hurricane from the opposite quarter impelled the waters in the opposite

direction upon the city of Leyden, the lower parts of which were submerged for nearly two days, and 19,000 acres of land were inundated. These enormous losses led to the resolution on the part of the government to drain the lake. In order to effect this, a canal 130 feet wide, 37 miles long, and 9 feet deep, was cut round the lake in order to isolate it, and provide for carrying on the water-traffic, formerly carried on over the lake. The mouths of all the watercourses entering the lake were also dammed up, and this vast body of water was now left without extraneous supplies. The area of water thus enclosed was rather more than 70 square miles, and the quantity to be lifted by pumping was estimated at about 1,000,000,000 tons!

The machinery formerly used to drain this low-lying country was principally moved by wind-power. Twelve thousand windmills, with an aggregate power of 60,000 horses, is required to prevent two-thirds of the kingdom of the Netherlands from relapsing to the state of morass and lake from which it has been rescued. A few small steam-engines were also used. In pursuance of the decision of the government, vast preparations were made for pumping dry this enormous reservoir of water. Three immense steam-engines, said to be the largest in the world, were constructed in England for this purpose. These engines have two steam cylinders, one of 84 inches in diameter, placed within another of 144 inches diameter. Both are fitted with pistons; the outer one is annular, or ring-shaped, and the two are united to a great cross-head or cap. The effective weight of these with parts of the engine attached is nearly 90 tons. The engine is on the high-pressure expansive condensing principle.

The engine-house is a circular tower, on the walls of which are arranged eleven large cast-iron balance-beams, which radiate from the centre of the engine.

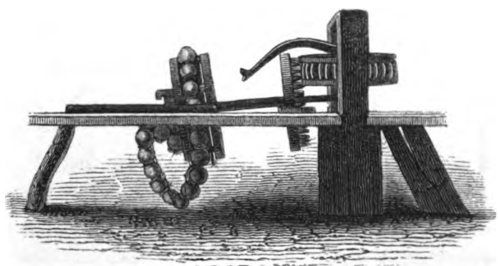
Their inner ends, furnished with rollers, are brought under the circular body of the great cap, and their outer ends are connected to the pistons of eleven pumps of 63 inches diameter each. The stroke of both ends is 10 feet, and the discharge from the pumps is 66 tons of water at every stroke! The water is lifted by the pumps into the canal, from which it passes off toward the sea-sluices. The total weight of iron employed for a single engine with its pumps is 640 tons. The united action of these three colossal engines discharges about 2,800,000 tons of water per twenty-four hours.

A more striking example of the use of the common pump could scarcely be selected. It will be observed that this colossal apparatus differs in no essential respect as regards the pumping machinery from ordinary lift-pumps. Drainage has, however, been very extensively carried on in this country also by aid of the steam-engine, and especially by Mr. Gurney. The fens of Lincolnshire and Cambridgeshire have been largely drained. Not less than 680,000 acres, once in a state of morass, are now rich in corn and cattle. The machinery used by Mr. Gurney for raising the water has been in all cases a series of scoop-wheels. These scoop-wheels somewhat resemble the undershot wheel of a water-mill; but instead of being turned by the impulse of the water they are used to lift it, and are kept in motion by steam-power. The float-boards of the wheels are made of wood, and fitted to work in a trough of masonry. This trough communicates at one end with the main drain, and at the higher end with the river, the water in the river being kept out by a pair of pointing-doors, like the lock-gates of a canal, which close when the engine ceases to work. In one of these engines the wheel is 40 feet in diameter, and is driven by an engine of 80-horse power.

The largest quantity of water delivered by one of

these engines is from Deeping Fen, near Spalding. This fen contains 25,000 acres, and is drained by two steam-engines, one of 80, and one of 60-horse power. The quantity discharged by the 80-horse engine is nearly five tons of water in a second, or about 16,200 tons of water in an hour. These engines were erected in 1825, and at that time the district was kept in a half-cultivated state by the help of forty-four windmills, the land being at times wholly under water. It now grows excellent wheat.

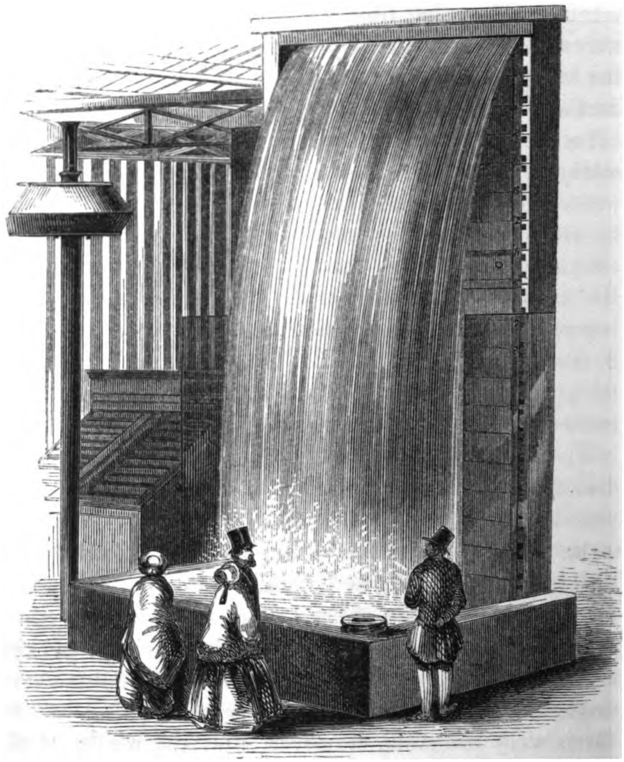
It is a curious fact, that the system here so extensively employed has in a modified form long been used in India,



in the simple but effectual engine called the Persian Wheel; and at the Great Exhibition was shown a model illustrating the nature of the apparatus employed, which is represented in the cut. It is simply a series of buckets made to revolve, and discharging their contents into a trough, which carries the water away.

It is very probable, however, that the whole of the apparatus at present in use will shortly be replaced by the extraordinary instrumen called Appold's centrifugal pump,—a machine, whose surprising performance will always be regarded as one of the most striking features developed by the late Exhibition. In the machinery department stood a tall wooden case, as high as the

roof, with a large reservoir at the bottom. By touching a lever, this immense case was converted into a cascade. A mimic river rose within it and gushed out at the top in surprising volume. The accompanying engraving was taken from a photograph of this apparatus in the



act of discharging its contents. On the side of the case is shown the comparative size of the disc which produced the vast body of falling water represented.

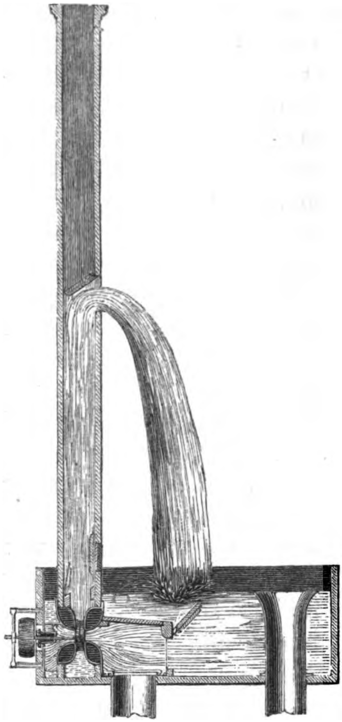
It has been stated by an eminent authority, that the ordinary pump is one of the worst machines, considered

in a mechanical sense. The ordinary pump only yields in its best forms 45 per cent. of work, the remainder of the motive power employed in it being lost through its defective arrangements. Some of the worst kinds of pumps yield only 18 per cent. of work, and thus absorb the enormous amount of 72 per cent. in overcoming the resistance, friction, &c. These defects, which to a certain extent are almost irreparable, from the construction of the apparatus, have led to the introduction of a new class of hydraulic engine, appropriately called centrifugal pumps, and to this class the remarkable pump just noticed belongs. In these pumps, water, admitted at the axis of a hollow wheel traversed by vanes and made to revolve rapidly, is expelled at its circumference. The pipe by which the water reaches the axis of the wheel (or the reservoir which feeds it) becomes, under these circumstances, a suction pipe; and if the reservoir into which the water is received from the periphery of the wheel be closed, and a pipe be carried from it upwards, the latter becomes a force pipe.

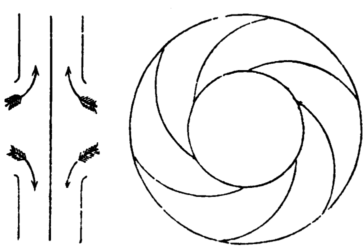
The centrifugal pump is by no means an entirely new discovery. It has been in use in America for many years, and also in France. But its practical introduction on an effective principle, and on a large scale, may be justly regarded as one of the useful results of the Great Exhibition of 1851; and there appears little reason to doubt that when its utility becomes fully known, and the cases in which it is most applicable are defined, the centrifugal pump will become the most valuable machine of its class yet introduced. Let us now describe Mr. Appold's arrangement, the success of which was such that it received the Council medal on the great occasion referred to.

Suspended on a horizontal axis, and immersed below the level of the pond or reservoir, at the lower part of the upright case shown in the cut, is the pumping

instrument, which is 12 inches in diameter and 3 inches deep. Its form will be comprehended by the following diagram.



It consists of two circular plates, with central apertures in each — the space between them is divided into compartments by the spiral plates shown in the diagram; and there is a third disc interposed between the two outer discs, to prevent the currents which are entering through the central apertures from impinging directly against each other. From this explanation it will be readily seen that, if we turn the instrument in the proper direction, the several spiral blades will act like wedges on the water contained in the disc, and cause it to flow towards the circumference. As this flow goes on, fresh water enters through the central aperture in the direction of the arrows, taking



the place of that which has been displaced, and thus a constant flow is kept up from the centre to the circumference. As the velocity of the pump increases, centrifugal force is added to the

wedge-like action already described; and thus the lifting force is compounded of two movements, namely, the inclined action (which is like that of a screw-propeller in water), and the centrifugal effort produced by rotation.

To make this centrifugal effort available as a lift, the instrument is insulated in an immersed case (see engraving), and the momentum due to the velocity with which the water rushes outward causes it to rise in the box, and thus it is forced to ascend to the desired height.

The new features in Mr. Appold's pump are the great duty performed by so small an instrument, and the reduced per centage of lost effect, notwithstanding the rapid rotation of the pump,—results which persons versed in the phenomena of fluids would hardly have been prepared to expect. Thus Mr. Appold's pump makes 600 revolutions per minute, and, at that rate, does an average duty of 70 per cent. on the power employed. This speed also gives a radial velocity to the water when leaving the periphery of the pump of above twenty-one miles an hour; and yet the effort produced is calculated as being at least equal to that of any other hydraulic machine, however slowly the water may be made to move by or through it.

The highest elevation to which the water has been raised with the 1-foot pump is 67 feet 8 in. with 1,322 revolutions per minute, being less than the calculated height, which may, however, be accounted for by the leakage due to the extra strain.

While the 1-foot pump is raising eight tons of water 5 feet 6 inches high per minute, there is no greater strain on any part of the pump than 160 ℔. on the 6-inch drum, which is equal to a leverage of 3 inches; and, as an illustration of the smallness of the risk of stoppage from anything getting into the pump, we

may mention that it will pass almost anything that is small enough, there being no valves. A quantity of walnuts—about half a gallon—were thrown into the 1-foot pump all at once when it was at full speed, and they passed through without crushing a shell.

One of the results of the good performance of this machine at the Exhibition was, that a much larger one was shortly after constructed for the drainage of Whittlesea Mere. The following notice from the pages of the Illustrated London News, will give an interesting account of this application of the pump to practical purposes:—

"Those who visited the Machinery department of the Crystal Palace will remember that one of its many objects of attraction was Appold's Centrifugal Pump, which poured forth a voluminous cascade, to the great delight of a constant throng of spectators. But though the performance of the pump thus afforded amusement, there was a strong opinion expressed by many of our most eminent engineers that its practical capabilities were worthless, and that it would prove to be nothing more than an ingenious toy. Not so, however, thought all who saw it; and Mr. Wells, of Holme Wood, Hunts, felt so confident of its merits, that he determined to have one of these pumps erected on a large scale on that part of his property over which, little more than a twelvemonth since, flowed the waters of Whittlesea Mere: and, by means of Appold's invention, complete and keep up the drainage of 3,000 acres of fen land. The works were accordingly erected, and proceeded so rapidly, that on the 12th instant a large party were assembled to witness the formal opening of the undertaking. It was not until then that the full powers of the centrifugal pump were understood; for that which Mr. Appold exhibited in the Crystal Palace, was a mere model of, and 20¼ times smaller than, the one erected on Whittlesea Mere.

The opening of the latter was therefore looked forward to very anxiously, as the success of the experiments then made would determine whether the prejudices that had been raised against the pump were groundless or not. Among those present were many practical men, who, from their long connexion with the Fens and the peculiar system of drainage which it requires, would be able to form a decisive judgment on the merits of the invention before them. The centrifugal pump was then put through a series of experiments, all of which were eminently successful, and fully satisfied those who had come full of doubts and prejudices, that a new era had opened in our great drainage works. The wheel from which the pump derives its name is four feet six inches in diameter; and after a few revolutions the troubled water rose to the top of the sluice, and was hurled over the gauge boards in a roaring torrent that fell with a discharge of 16,521 gallons of water per minute. When the machine was working under a five-feet lift, the quantity of water discharged was about 74½ tons per minute; and by removing some of the gauge boards, and diminishing the lift to between two and three feet, the volume of water discharged was 101 tons per minute; a quantity which would cover the area of an acre of land to the depth of an inch. Some idea may therefore be formed of the effective power of the machine. The pump is connected, by a simple wheel gearing, to an elegant steam-engine of 25-horse power, working on the high-pressure expansive and condensing principle, with two cylinders. The boiler is of a very simple construction, affording an immense amount of heating surface, thus economising fuel; while at the same time it possesses the form of the greatest strength, having none of its parts of large diameter, and presenting no flat surfaces. Its pressure is 3,500 tons, being about 35 pounds per square inch."

Two other centrifugal pumps were also shown at the Great Exhibition, and attracted some attention. One of these was Mr. Bessemer's, and it was a very curious machine. It was said to be capable of discharging twenty tons of water per minute, and of draining one acre of land per hour, if covered with one foot of water. The distinguishing features of this engine, were its combination with the steam-engine, the disc and shaft of the pump serving also the purpose of fly-wheel and shaft to the engine. There was no intermediate gearing, no valves or rubbing surface whatever in the pump. It was kept in motion by steam from the pipes in the building. On comparison of the amount of work done by this engine as contrasted with that of Mr. Appold, it was found very far inferior. Yet the relative size of the machines was most disproportionate. Mr. Appold's pump was no larger than a dinner-plate, while Mr. Bessemer's was six feet in diameter! Yet the diminutive engine by its side did an immense amount of work more than its larger competitor. In Mr. Bessemer's pump the arms were radial, and the discs between which they were placed were dished, so that at the edges they were one or two inches apart, and at the centre about five or six. Upon the direction of these arms or vanes appears to depend much of the efficacy of the pump, for it was found that a small apparatus like Mr. Appold's in all respects except that the arms were straight, gave out only 24 per cent. of duty, while Mr. Appold's pump gave out nearly three times as much, namely, 66 per cent., a result due to the arrangement of the arms in a proper direction. In these experiments it was found that by slightly curving the straight arms, an immediate improvement was effected, and nearly twice the amount of work was done by the same power. Nothing could have more clearly shown the importance of this fact than such a result.

A third centrifugal pump was also shown by Mr. Gwynne. This pump differed from the others in having only one arm, which was straight. The apparatus in which it was set to work did not materially differ from that of Mr. Appold, but it was thought by its inventor that the pump was capable of performing much more work than either of the others. The single arm was driven by bands and pulleys, as in Mr. Appold's, and the pump certainly proved in a degree efficient. It could scarcely have been anticipated that a single arm could have delivered any considerable amount of water at any velocity. But when tried the fact was certainly established, though by no means to the extent anticipated by its over sanguine inventor. In order, however, to test the respective power of this pump, with that of Mr. Appold, one was made under Mr. Gwynne's superintendence, and was fitted in Mr. Appold's case. The trial was then made. But, although this pump was driven at a greater velocity than Mr. Appold's, it lifted only one quarter of the water at the ten feet lift, and at the middle or 17 feet lift, it would not discharge anything at all.

Among other hydraulic engines used in the arts in addition to pumps of various kinds, may be mentioned the ingenious instrument called the water ram, for lifting water to a considerable height. This apparatus was invented by an Englishman, in 1772, but it was greatly improved and rendered self-acting by the celebrated Montgolfier, in France. Hydraulic rams, from their simplicity, are useful machines for supplying moderate quantities of water to a considerable height, and are principally employed for the supply of country mansions, in cases where a small stream is near at hand.

The action is well known, and consists merely of an arrangement of a couple of valves placed in a pipe, so that the running water, when it has acquired a certain

velocity, has a tendency to close the lower one, which was previously kept down and open by its own weight; and then the reaction consequent on the momentum of the column of water suddenly stopped by the closing of this valve drives open the upper valve, and expends itself against the rising column, which is driven up some distance and delivered into a tank. On the column of water coming to rest, the upper valve falls to, from the weight of water above it, and the lower one again falls open, till the water flowing through it has again acquired velocity enough to close it and repeat the operation. The force exerted by running water in a pipe is familiar enough to all, from the shock felt on suddenly closing a common tap-cock, which is often sufficient to burst the pipe, when the supply cistern is very high above the cock.

Another class of engines much used in the arts are those called hydro-extractors, or in other terms, engines for the removal of superfluous water. These engines are not very generally known, nor are they yet employed in a number of cases in which their use would be attended with much advantage. The principle upon which their construction is based, is as old as the act of trundling a mop for the purpose of removing its superabundant water. It is merely taking advantage of the centrifugal tendency of the water when in rapid motion. And if we suppose the mop to be whirled round still more rapidly, the result would be that in a few minutes it would be as dry as if it had not been in the water at all. An immense saving of time would be thus effected, for under any other circumstances it would occupy several hours at least in drying. With the addition of a few mechanical arrangements adapting the machines to the special purpose they are intended for, the hydro-extractors are made just upon this principle, and their action is attended with a wonderful economy of both time and labour.

This machine was invented by Mr. Seyrig many years ago, and has since become of great importance in a variety of industrial operations. Its action may be rendered intelligible by a momentary glance into the interior of a Lancashire printwork. The machine, consisting of a circular chest of cast-iron, surmounted by a shaft and cogs which communicate rotary motion to a perpendicular spindle rising out of the cast-iron case, stands near the calico-printer's wall. The air teems with moisture, and the stone floor is covered with puddles; it might, therefore, be supposed that any other rather than a drying operation was about to be fulfilled by this engine, the bottom of which drips with wet. It is now at rest. The attendant appears with a pile of cotton dresses, the water pouring from them in a copious stream on each side of the wheelbarrow in which they are placed. He takes up a quantity of the wet cloth, and places it in the wire basket within the machine connected with the upright spindle, and revolving with it when it revolves. Nothing could be more charged with water than this mass of printed calico, every fibre of which is penetrated by it. But a great and almost magical effect is now about to be produced.

The lid of the machine is shut down, and by shifting a strap the cog-wheels above it revolve, and the spindle with the basket and clothes below begin to turn. At first the movement is slow, in a few seconds it is obviously quickening, in half a minute it becomes extremely rapid, the pace still increasing, the strap flies faster and faster, the cog-wheels whirl round with a still rising velocity, the spindle hums on its bearings, and quivering with the furious speed, loses to the sight its revolving motion and seems only like a vibrating shaft. The whole machine trembles within itself, and the solid ground feels the violence of the effort. In three minutes the cloth which was stationary at the commencement of

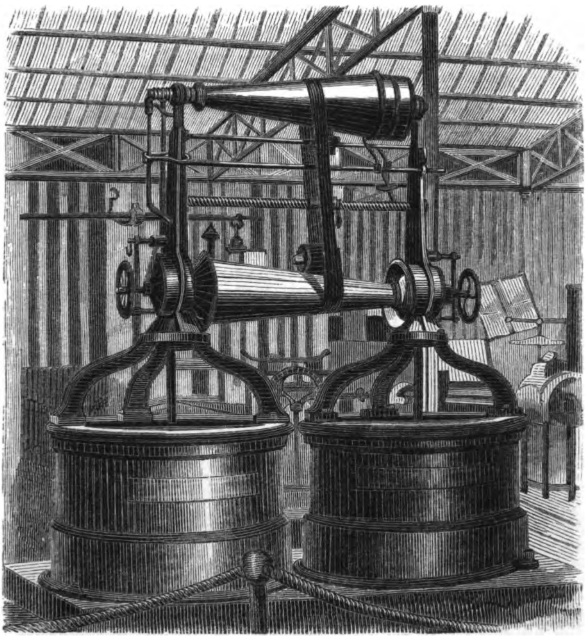
that short period, is flying round faster than the fastest express train on the iron road. In a few seconds more the task is done, the labouring strap flies on to the loose pulley and thus escapes from its work. The machine trembles less and less, the rotary movement of the spindle becomes again visible to the eye, until at length it ceases to move. The lid is then opened and the calico taken out of the machine—dry, as absolutely dry as if it had hung upon a clothes' line for half a summer's day. The water flying from the revolving cloth was gathered by the interior of the case of the machine, fell to the bottom, and thence gurgled away into the drains.

These machines are, however, as frequently used for washing as they are for drying, paradoxical as the statement may seem. And—still more curiously—they may be made to wash and to dry the same piece of goods without removing it; this is accomplished in the following manner. The clothes to be washed are put into the engine, which is then made to revolve. While it is in moderately rapid motion, a jet of water is introduced into the centre of the machine, and flying toward its circumference passes through the interstices of the cloth, removing all traces of dirt, and then falls down to the bottom and passes out of the machine. This is continued until it is considered that the goods are sufficiently cleaned. The water is then stopped, and the machine rapidly revolving, quickly expels every trace of moisture from the cloth, and in a few minutes this mechanical laundry-maid has completed its office, and has washed and dried the cloth intrusted to it.

These machines have also been extensively used in the sugar manufacture, for the removal of the impurities from both moist and refined sugar. This is done in the same way as the cleansing process just described, only that the cleansing fluid is a stream of pure syrup, which

drives out the impurities before it. These machines are very fully described in the little treatise on Food, as exhibited in 1851.*

Passing now from the consideration of those machines, which are employed in connexion with water in its mechanical state, we may notice a few which are em-



ployed for acting upon water in a chemical manner. Under this head may be noticed soda-water machines. It is familiarly known that all aërated waters are charged with carbonic acid gas, or with some other gas, by an apparatus which forces the gas into the water and mixes it completely, so that a large quantity of the gas is dis-

* "Substances used as Food."

solved,—this apparatus we shall presently notice. A much more simple arrangement has, however, been recently patented, and a description of it will assist the reader to comprehend the detail of the ordinary machine. Carbonic acid gas is obtained by acting on chalk by means of sulphuric acid and water,—the chalk gives up its carbonic acid in a gaseous state, and, combining with the sulphuric acid, forms sulphate of lime.

The water is impregnated with the gas in excess, by connecting the vessel which contains the sulphuric acid employed to generate the carbonic acid gas with a second vessel, called a "generator" (in which the gas is made), by means of a supply pipe, in such a manner as to cause an equal pressure of gas both above and below the acid. By means of a trap, any desired quantity is admitted into the generator at proper intervals, and the pressure of the gas increased to any required extent. The pressure thus obtained is made available in forcing an excess of the carbonic acid gas into the liquid to be impregnated.

The gas generator and the purifier are made of hammered copper, tinned inside, and are placed on a counter or table. Each of these vessels is constructed in two parts, being connected together by means of screw-bolts passing through the flanges of each vessel. On the top of the "generator" the acid vessel is attached. This is also made of hammered copper, but, instead of being tinned within, is lined with lead, in order to resist the action of the acid. The acid is admitted into the generator through a passage, which is furnished with a proper plug, covered also with lead, the plug being moved by a handle.

In order to equalise the pressure of the gas above and below the acid, a communication is made between the vessel which contains it and the generator by means of a pipe, and the atmospheric air is allowed to escape by

means of a tap at the top of the vessel. The chalk is introduced into the generator by an opening left for the purpose. The generator and purifier are connected together by a leaden pipe, the passage through which is opened or closed by means of a tap, from which a pipe is extended to within 4 or 5 inches of the bottom of the purifier. A pressure gauge, for the purpose of ascertaining the pressure of the gas in the purifier, is fixed in connexion therewith.

From the purifier, a branch pipe, with proper tap, leads to the tank containing the liquid to be impregnated with acid, the end of which pipe is carried to within 2 or 3 inches of the bottom of the cylinder. During the operation of mixing the gas with the chalk or other alkali, the latter is kept in motion by an agitator, which is turned by hand in the ordinary way.

The action of the apparatus may be thus described. When the generator is charged with its complement of water and chalk, the acid vessel with the sulphuric acid, and the purifier with the water,—all the taps and openings being closed,—the acid is admitted into the vessel containing the chalk, which is kept in a state of agitation during the time of impregnation. The atmospheric air before in vessel is forced, by the action of the acid on the chalk, and the consequent development of carbonic acid gas, to the top of the vessel, whence it escapes by the tap hole provided for the purpose. On this tap being closed, the whole of the generator is occupied with the gas; the gas is then admitted into the purifier, and passing through the water therein, occupies the upper part of the vessel. From the purifier the gas is next admitted to the interior of the cylinder containing the water to be impregnated; the water being kept in a state of agitation, in order to facilitate its solution in the gas.

A tap of peculiar construction forms part of Mr. Cox's

patented invention. It consists of a cylinder of metal, having an aperture at one end in the centre, but bored through so as to emerge eccentric to the other end. This cylinder is placed between two clips bolted together, having on their contiguous faces circular recesses, in which the cylinder is placed; one clip being connected with the *influx*, and the other with the *efflux* pipe. The opening and shutting the passage for the flow of the liquid is regulated by the position of the eccentric.

The following notice by the writer, originally published in the Edinburgh Journal, will give an account of the machines more generally in use in the manufacture of aërated waters.

The manufactory of which we purpose giving a description, is probably one of the most extensive in the provinces; and with several advantages accruing from its site, combines all the most perfect methods now in use for the preparation of these largely consumed fluids. It is situated on the banks of the river Clwyd, in the little town of Ruthin, deeply embosomed in the vale well known to Welsh tourists as the Vale of Clwyd. Its supply of water, which is so essential a portion of the manufacture, is probably unrivalled. This appears due to the fact of the geological basis of the district being he red sandstone. The water of the river percolates directly through a thick bed of this rock, becoming thus perfectly filtered before it is drawn for the use of the manufactory. Probably no water contains so minute a portion of mineral impurities, and upon this seems to depend the success of the manufacture. Passing by the engine-room and bottle-washing machinery,—in which is an ingenious contrivance whereby the bottles to be washed fill themselves in the proper manner with water—the soda-water mechanism is arranged in a separate portion of the manufactory. A compact machine, something like the large model of a beam steam-engine, is at

work at a rapid rate before us. On one side are the driving pulleys and fly-wheel, in the centre a polished reservoir of bell metal, and at the further end a solid metallic plunger, rapidly moving to and fro in the perpendicular direction. This is the force pump of the apparatus; and it is so arranged, that no extraneous matters of any kind can become mixed with the fluid. At the opposite end of the machine is a copper vessel, plated in the interior, which holds a graduated supply of the alkaline water, from thence drawn by the pump and sent into the reservoir. This vessel is itself supplied by a pipe, proceeding from an immense tank of slate in another part of the manufactory. Near the pump two pipes converge; one comes from the vessel just mentioned, the other proceeds directly from a very large gas-holder of copper, also out of sight; at this point two regulating indices are placed, on which is engraved "Open," "Shut," with a number of intermediate degrees. By this means the supply of water and of gas is conveniently adjusted, according to the degree to which it is required to charge the fluid. An arrangement of cog-wheels drives with great rapidity a spindle, to which fans are fixed, which revolves inside the spherical reservoir, and thus agitates and mingles intimately the gas and water.

From this part of the machine the now perfectly aërated fluid descends by a strong pipe to the bottling engine. At the top of this reservoir is a safety-valve heavily loaded; and to ensure the perfect saturation of the water with the gas, this valve is kept by the pressure within just on the lift, and not unfrequently blows off with considerable noise. The bottling of a fluid thus highly charged with elastic gas is, as may well be imagined, an operation of no common difficulty. In the greater number of manufactories it is still done by hand: the cork, hastily thrust in, is struck down into the bottle

with a wooden mallet, greatly to the risk of the bottler and the bottle; while it has also this disadvantage, that the hand is unable to resist a pressure of more than three or four atmospheres, and hence the cork resists all efforts to drive it down until a large part of the charge has escaped. All these objections are obviated by the ingenious machine called the bottling engine. This is fixed in an upright position, at a little distance from the machine in which the fluid is prepared; and its supply is derived from a strong pipe connected with the reservoir. There is a sort of treddle, worked by the foot, having a wooden cup which receives the bottom of the bottle; the neck of the bottle is then placed inside a hollow collar of bell-metal, at the upper end of which a cork is thrust down from above, and in the side are holes connected with the pipe conveying the fluid. Above, there is a plunger, intended to force the cork down, worked by a powerful lever in the bottler's hand. The tap is turned, the fluid rushes in and fills the bottle, and the lever is forcibly dragged down, bringing the metallic plunger with it, and burying the cork in the neck of the bottle. It is then quickly removed, taken by the hand of an assistant just behind, who straps it down with tinned iron wire, when it is again delivered to another, who wires it in the opposite direction, and thus the captive cork is held firmly down. The rapidity with which all this is effected can scarcely be believed. An expert bottler can often bottle off *two thousand five hundred bottles* as his day's work! The carbonic acid is obtained as usual, from chalk and sulphuric acid, and the materials are mixed in a leaden retort.

The machines last noticed form a sort of transition from apparatus adapted for operating upon water, and such as is used for acting upon air. For various purposes in the arts, a current of air in rapid motion is as

much required as water is needed for other purposes. Take, for example, the whole series of foundry operations—steel-grinding, lace-gassing, warp-drying, &c. In all these processes a blast of air is absolutely needed, and a good apparatus for producing it consequently becomes of much importance to the manufacturer.

The common bellows is an air-machine of the simplest kind, but is constructed upon very faulty principles, and is of course wholly unfit for the wants of the manufacturer. One of its chief defects lies in the interruption of its action, by reason of which it is not capable of giving out a regular and continuous stream of air. To effect this a new adjustment of its parts is necessary. The nozzle must communicate with a second chamber, in which the air can accumulate under pressure, and the pumping part of the bellows—its lower half—must throw the air into the reservoir, and not, as in the common bellows, directly through the nozzle. The smith's bellows is a better machine. Here there is a reservoir for the air, and the current is continuous and not intermittent. By connecting the arm acting on the blacksmith's bellows with the crank of a steam-engine or water-wheel a power air-pump of a simple kind is formed; and this sort of machine is often employed where a better one cannot be procured. The volume of air, however, which it is capable of giving out is very small, and cannot be made to receive any high degree of velocity. The pressure, however, up to which the reservoir can be loaded by weights is an advantage, since a small but very powerful jet of air can thus be procured.

Air machines can, in fact, be arranged under the same head as hydraulic-machines. Some are constructed upon the pumping principle, to use a homely term, others upon the centrifugal; and since air obeys many of the laws of fluids, in its motion at least, this is only what might have been *à priori* anticipated. Under the

class of pumping-engines we must reckon the bellows, and all kindred apparatus. For small forges, as in machine-shops for the smaller parts of machines, an improved kind of smith's bellows is constructed, and forms a very superior and excellent apparatus for the limited duty it is required to fulfil. At the Great Exhibition one of these improved bellows was shown by a French machinist, and was of such good construction as to be honoured with a prize medal. M. Enfer's apparatus is a great improvement upon the blacksmith's bellows, and gives a continuous and steady blast. It is composed of two air-vessels communicating by tin pipes, in one of which a cylindrical bellows is worked, and the other serves as a reservoir. By simple but ingenious contrivances, the pressure of the air in the second air-vessel or reservoir is regulated, and the bellows is made to drive air into it both when it ascends and descends. This machine, or one very similar to it, is now employed in all workshops where forges are used for urging the fire, and for that purpose they are the best adapted of any kind of air-engine. For just as it is found in hydraulics that a pump is the only engine which can be satisfactorily used for driving out water at a high pressure, and that centrifugal engines are only fit for low lifts and large quantities; so in this case, the centrifugal air-engine is little adapted to the wants of the forge, where a compact and powerful blast is needed more than a broad current of air.

Some years ago great interest was excited in a machine for domestic use, which in a short time threatened to put the bellows aside altogether. This machine by turning a handle threw out a volume of air, which, on being directed to the fire, was found far more efficacious in its influence than the old apparatus. The machine resembled a pistol, and was furnished at the handle end with a wheel, which set in motion an agitator within.

On turning round the wheel, the agitator—or fan, more properly—rapidly rotated, drawing in air at its sides, and throwing it out in a strong current at the nozzle of the instrument. Since then this most useful and ingenious apparatus has become very popular, and is now familiarly known. It is invaluable in the laboratory of the chemist for the purpose of obtaining a powerful heat in the small furnaces used in assaying, &c.; and in such instances it is an exact type of the fanning-engine employed on the large scale in the arts and manufactures.

The principles on which the blowing fan is made are precisely those previously discussed in noticing the centrifugal pump. Air is drawn in at the openings around the axis of the machine, it then passes along the vanes, and is driven off at their tips into the tube connected with the apparatus. Ordinarily these fans have their vanes quite straight, and, in revolving at the high velocity to which they are kept, they give out a most peculiar sound, not unlike the hum of a humming-top. Wherever a blowing-fan is used, driven by steam-power, the noise it creates is audible for some hundreds of yards around it, and proves often the contrary of an agreeable sound to the quieter neighbourhood in its vicinity.

An improved form of blower has, however, been recently introduced, the construction of which closely resembles that adopted by Mr. Appold in his centrifugal pump. This machine was exhibited in 1851 by its inventor, Mr. Lloyd, and a series of careful experiments were made in order to test its capabilities. The vanes of this blower are curved and its sides conical. The air enters into a space left for its admission about the axis, and is expelled when the vanes are put rapidly in motion at its periphery into a case which surrounds it, from which it is carried by a pipe, and the blast is

applied by a nozzle. The machine is also capable of acting as an exhauster as well as for blowing purposes. In this form it differs from the blower in not having an outside case. The air is conducted from the space to be exhausted by a pipe to the central part of the exhauster, and is expelled at its periphery. The action of these machines is, curiously enough, quite noiseless, in which respect they are an immense improvement on the common blowing-fans. The power required to drive them is also less than that necessary for the other kinds. After carefully testing this machine, it was found to yield a larger proportion of useful effect than the common ones, and also to work without noise.

The application of these blowing-fans in the arts is very varied. In iron-foundries they are of constant employment, and the atmospheric thrill they produce is often sufficient to indicate the position which they occupy. They produce a powerful blast, which is directed through a nozzle into the smelting furnace, and by means of which the materials therein placed are speedily raised to the highest state of ignition. As exhausters these fans are also much used. Thus, they are employed to withdraw from the needle-pointer those minute portions of steel floating in the air which render his life so brief and painful. They are also used to absorb the fine particles of cotton which are removed in the lace-gassing operation. They are also much used in cotton-factories to carry away the fine dust so abundantly given out in the preliminary part of cotton manufacture. Wheresoever, in fact, a free current of air is required, or a gentle exhaustive effect is to be produced, in such cases the blowing-fan becomes a most serviceable and valued instrument.

The air-pump is not so much employed in the arts as for philosophical purposes. It is, however, an instrument of primary consequence in the construction of the

low-pressure steam-engine, for keeping up the vacuum of the condensing chamber, in the manufacture of sugar, and also in the preparation of medicinal substances. On the great scale it is also applied in a most ingenious manner in seasoning wood. The timber is placed in a large vessel of iron half-filled with the seasoning solution, the whole is then hermetically secured, and the air is exhausted by the air-pump driven by a steam-engine. A vacuum having thus been obtained, and the air removed from the cells of the wood, air is re-admitted into the chamber, and by its pressure on the surface, the liquid is driven into the wood, thoroughly penetrating every interstice.

A very different class of machines must now receive a brief notice. These are machines used for pulverizing and similar operations, such as grinding, kneading, mixing of soft substances, &c. The construction of the ordinary mill must be familiar to every person. The stones used for grinding are of a very peculiar description, and the best kind were formerly only to be procured in France. They are called burr-stones, and are still imported into this country in considerable quantities. These stones possess both geological and physical characters of much interest. They are met with only in the Paris basin and the adjoining districts, in the lacustrine, or fresh-water deposits (*Pleistocene*), occurring in beds either continuous or interrupted, and generally mixed up with beds of sand or of ferruginous marls, which penetrate between them, filling up their fissures and honeycomb cavities. The beds sometimes contain no organic forms, at others they seem to be full of fresh-water shells and land plants, which have assumed a silicious character. The texture of the stones is essentially cellular, the cells or cavities being irregular in number, size, and shape, and are frequently traversed by thin plates, or coarse lines, of silica. They

are quarried close to the surface, and are cut on the spot into parallelopipedal pieces, which are bound together by iron hoops, and then form millstones. They are either of a whitish, yellowish, greyish, or bluish colour: the two latter are the most valuable. The best kind are only to be procured at a place called La Ferté-sous-Jouarre.

Mills fitted with these stones are now very generally supplied with an arrangement for aërating the flour while it is being ground. It is found that the great friction and pressure necessary to reduce corn to powder heats it so much as to render it very liable to undergo decomposition, and the only method of preventing this is by introducing a current of air between the stones, and thus keeping the flour cool. An active circulation of fresh air is kept up, to which the meal is exposed, and the flour is thus preserved from injury.

One of the most magnificent flour-mills in this country is in the Royal Dockyard at Plymouth. This building is 240 feet long, and 70 feet in height. In the centre are two steam-engines of 45-horse power, on each side are 12 pairs of stones, each performing 123 revolutions in a minute, and grinding five bushels of corn per hour, so that when the mill is in full work 120 bushels of corn are ground in that time, and the flour is dressed by eight machines. The corn is laid on the upper floor, and then is conducted by spouts, first to screening-machines, or cylindrical sieves, arranged somewhat like an Archimedean screw. It is admitted at one end, and being cleaned of sand and dust in its passage, falls into a hopper, from which it passes by spouts to the mill-stones.

After flour is ground it requires to be purified from those parts which form the outer envelopes of the seed—the bran, as it is called. The machines usually employed consist of a kind of cylinder made of wire-cloth.

The flour is passed into this, and is brushed through the meshes of the cloth by brushes. That which falls from the upper part of the cylinder is the fine flour, and from the succeeding parts, the seconds, thirds, &c., the bran leaving it last of all. The flour is sometimes driven through the meshes of the cloth by means of fans, which are made to revolve very rapidly, and thus blow it through. The wire-cloth is extremely fine in its texture. In some specimens exhibited in 1851 there were 22,500 holes in a square inch! The wire of which this very fine cloth was made was also shown, and a length of 3,900 feet did not exceed once ounce in weight.

Connected with flour-mills is the ingenious machinery adopted for manufacturing biscuits and bread in many large establishments of recent origin. The vast requirements of our navy have led to the erection of a great establishment at Portsmouth for biscuit-baking. In this process, the ingredients being mixed in proper proportions, are subjected to the action of revolving knives, by which they are mixed. The dough thus formed is passed beneath heavy cast-iron rollers, moving horizontally along stout tables, which press it into huge masses, 6 feet long by 3 broad. After being cut into smaller pieces, and again subjected to the action of the rollers, thus quickly reducing all knots, and thoroughly mixing the dough, it is passed under a sheet roller while lying on large flat boards. The next operation is cutting the thin sheets of dough then prepared into properly-shaped biscuits. The shape adopted is that of the hexagon, for the same reason as that which appears to have dictated the instinct of the bee in forming its cells. If the circle had been the form used, it is evident that the pieces of dough left between the touching circles must have been unused, whereas, from the peculiar shape of the hexagon, the whole sheet of dough, with the exception of insignificant portions at the edges, goes to form biscuits. The

dough to be cut into biscuits being placed in the blanket, a frame moving vertically, having on its under surface sharp-edged hexagonal divisions, is brought down upon it, thus cutting at one operation 52 biscuits. To facilitate the removal of these to the oven, the frame is allowed to come down only a sufficient length to cut the cakes nearly, but not quite through. When baked, they are very easily separated. It may be supposed that the dough would be apt to adhere to the interstices between the sharp cutting edges. This is provided against; and here may be cited as an instance of that forethought displayed by inventors of truly practical and useful machines. A movable frame is placed between each cutting hexagonal periphery; and on the top of this is placed an iron ball weighing several ounces. The operation is simple. The frame descending cuts the 52 biscuits; the 52 frames give way to the superior pressure; but on the large cutting frame ascending, the 52 balls cause their corresponding frames to fall, projecting the dough, which is thus ready to be pulled out to the oven.

So admirably is this machinery arranged that it is quite automatic in its performance, and the biscuits are even conveyed into the oven by machinery.

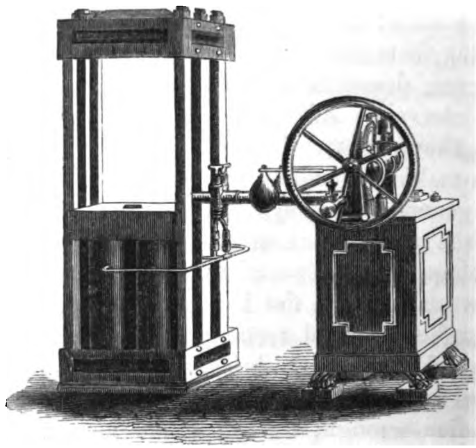
Somewhat analogous in its nature to this machinery is that now in use for making hollow bricks, pipes, &c. The material is first kneaded in appropriate mills to the consistency of dough, and is then submitted to the action of the machine. It is difficult to explain the mode of action of these engines in their curious operation of producing hollow masses of clay. But any one who has seen the production of macaroni at Naples will have an excellent idea of their principle, which is identical with that of the apparatus used by the Italian pastry-cooks. There is a hollow tube of iron, in the centre of which a small piece of round iron is fixed. The soft

clay is pressed into this tube at one end and driven out at the opposite, and in being squeezed through the rod of iron in the centre of the tube, by keeping the clay from being pressed into the middle, forms the hollow part, which is called the bore, in the soft clay as it passes on. The clay consequently emerges at the other end in a tubular form. By varying the shape of the tube any form can be given to the external part of the clay-pipe, and by varying the figure of the iron rod within any variety can also be communicated to the shape of the interior. Since these pipes are chiefly required in short lengths, some of the machines have a clever contrivance for cutting them into the right length. A wire, actuated by a lever, descends, and cuts through the mass at regular intervals. After the pipes are produced in the machine they are carried off and baked in ovens.

Brick-making machines are very ingenious, but are not so generally employed as pipe and tile machines. One of the most ingenious we have seen, is somewhat of the shape of a horizontal flat cast-iron wheel. This wheel is placed on a flat bed of masonry, and on its upper surface are laid rectangular moulds or boxes of the size and shape of the bricks. The under surface of the wheel is provided with teeth which work into those of a pinion wrought by the prime mover. Friction wheels guide the wheel in its circular movement, and a hopper containing the clay is placed in such a position that as the mould passes under it the clay drops therein, and is pressed forcibly and its surface scraped by a revolving conical roller placed on the under surface of the hopper. The mode of removing the bricks is remarkably ingenious. In the inside of each mould, a piston works vertically; the piston rod passes through a hole in the under part of the mould, and is provided at its lower extremity with a small friction wheel running in contact with an inclined way placed on the

masonry and under the wheel. The moulds filled with clay are carried round, and the piston rods gradually lift up the clay as they traverse the inclined plane until at length the clay is forced out in the form of a perfect brick which is carried away upon an endless belt, while the mould goes round and receives a second charge of clay.

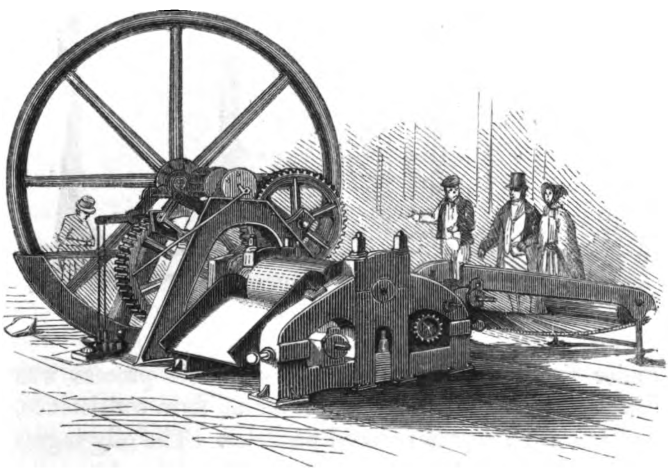
A very useful and necessary instrument to the manufacturer is the hydraulic press, which has already been noticed in a preceding page. The subjoined cut shows



an interesting modification of it, consisting of four cylinders, capable of developing immense compressive force. It is made by Messrs. Hick, of Bolton.

Among machines for crushing and grinding must be reckoned the enormous engine for crushing sugar-canes, exhibited by Messrs. Robinson, in Hyde Park, in 1851, shown on the next page. This immense machine, though imposing in appearance and in power, was very simple in its construction. On one side was an endless belt upon which the canes to be crushed

were laid, and by which they were carried forward and presented to heavy steel rollers. The canes pass between these rollers and receive a most severe pressure by which their juices are extracted, and they are then thrown out on the opposite side. The machine was a combination of a steam-engine and crushing-mill, for a steam-engine with an oscillating cylinder was attached to the fly-wheel crank, and gave motion to the rollers. The whole framework of these engines is necessarily of enormous strength and colossal proportions. In the best constructed engines there is a provision made for accidental introduction of stones or other resisting materials, which, in their progress through the rollers, would inflict much damage on them, by

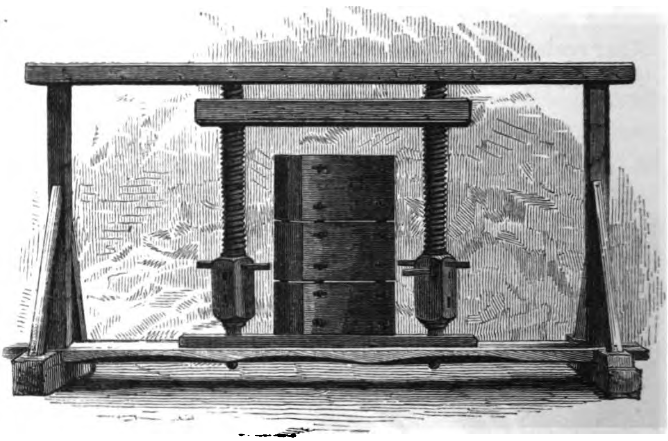


attaching a powerful spring beam to the rollers, which yields to unusual pressure, and thus prevents injury.

The cut on the next page exhibits a powerful but simple press, used by the natives of India for packing cotton into a very small compass.

The last of the machines to which we shall direct

attention under this present chapter is the apparatus used for the preparation of chocolate, and which, trivial as its purpose may possibly seem, was nevertheless honoured with the Council Medal of the Exhibition. This engine consisted of a flat circular bed of polished cast-iron, surrounded with a metal rim, and thus forming a circular trough. In the centre was a vertical axis carrying three polished rollers around this trough, and pressing upon its bed. The material to be reduced to a paste was placed on the bed and was carried continually



under the action of the rollers, and this process was continued until all the mass was of uniform consistence, and free from any unreduced particles. The oily ingredients of the nut suffice to render the mass of a pasty substance, and the chocolate produced by it was said to be of better quality than that made in the ordinary way. In many of the shop windows in Paris these machines are displayed in full operation, and are generally driven by elegant steam-engines. The whole of these machines were kept in a state of extreme cleanliness.

With the present chapter we conclude our notice of the machinery employed for industrial purposes. Our endeavour has been to present a sketch of most of the engines really important in the arts and manufactures. But in a few brief pages such as ours, little more than a general outline could be attempted, and it is very possible that many interesting machines have been left unnoticed. Thus much may, however, be said, that any person who has carefully read the preceding chapters on this subject, will have had supplied to him the materials for much thought and instruction. He will have seen power created, developed, controlled, directed, and applied. He will have contemplated man in his finest specimens of handiwork, and have received triumphant evidences of the power and genius of that mechanical mind of which this country has good reason to be proud.

Let us, however, not fail to add, in conclusion, these are God's gifts. Very early portions of Holy Writ teach us that the inventive, adaptive, and constructive genius of man, is a peculiar bestowal from Him who alone is excellent in all His works. In view of this thought, it may as truly be said, that God made the steam-engine as that He created the coal and water by which it operates. The only difference lies in this— that he employed man as His instrument in the construction of the machine. And no one who contemplates the results which this machine has been instrumental in bringing about, and the effects which it has exercised upon the social position and progress of the human family, can doubt that the original invention of so wondrous an apparatus, is to be attributed to a higher source than the unaided efforts of the highest mechanical engineer.

CHAPTER VII.

THE INSTRUMENTS OF PHILOSOPHY.

THE lapse of two centuries has produced a wonderful change in the progress of science and in the instruments it has employed. If we go back in thought to some of the early meetings of the present philosophical and distinguished body called the Royal Society, we shall find in how remarkable a manner the science of the present day differs from what was called science in that early time. The following extracts from the minutes of their early meetings will show the nature of these assemblies, and the state of philosophy at the time when they were held. "Mr. Boyle was desired to bring in the name of the place in Brazil where that wood is that attracts fishes, and also of the fish that turns to the wind when suspended by a thread. To inquire whether the flakes of snow are bigger or less in Teneriffe than in England. Mr. Ponez was intreated to send to Bantam for that poison which is related to be so quick as to turn a man's blood suddenly to gelly. The Duke of Buckingham promised to bring into the society a piece of a unicorn's horne. That the dyving-engine be goeing forward with all speed and the treasurer to procure the lead and moneys. Several physicians were appointed

curators of the proposition made by Sir G. Talbot, to torment a man presently with the sympatheticall powder. A circle was made of powder of unicorne's horne and a spider set in the middle of it, but it immediately ran out several times repeated."

With all this childishness there was a deep thirst after truth in the minds of the early philosophers, and whilst they often spent valuable time in investigating the most absurd and ridiculous fables, they also were not indolent in conducting experimental inquiries into the properties, nature, and state of bodies in the physical world. For this purpose they contrived many simple but excellent instruments, and the results of their labours may be appreciated by a perusal of the subjoined note * on the state of philosophy at this time, originally published by the writer of this volume.

* "The experiments which were tried by them during the first ten years of the existence of this zealous association of philosophers, surprise us by their number, and in many instances by their magnitude and difficulty. Their results as to the nature of what from all antiquity, or at any rate since the days of Peripatetic Philosophy, has been regarded as an element—namely, fire—are admirable. They proved that fire was a state or condition of bodies, not itself an element, or having existence as such. Fire, say they, is only the act of the dissolution of heated combustible bodies by the air as a menstruum, and that heat and light are two inseparable effects of this dissolution; that flame is a dissolution of smoke, which consists of combustible particles carried upward by the heat of rarefied air; and that ashes are a part of the combustible body not dissoluble by the air. Their experiments to determine this point, upon the construction of various bodies, are equally good; and although oxygen was unknown to them, they showed that combustion depended on some ingredient in the air, which was removed from it by the burning body. They obtained the excellent result, that high temperature applied to combustible bodies, though it might cause their destruction, would not cause them to take fire and burn if deprived of air. Their investigations into the comparative heat of the flames of different combustibles are also good; and their attempts to determine the melting points of lead, tin, and other metals, valuable. A number of other investigations were carried on at a high temperature, the objects and design of which would have done no discredit to our own experimental era. Their experiments upon the air, in which Boyle greatly distinguished himself, have supplied science with facts, fresh and forcible at the present day. A number of experiments were made with the barometer on mountains, on the surface of the earth, and at the bottom of very deep pits, and at places far removed from each other. The machine called the air-gun was frequently in

The instruments of philosophy were necessarily at first of the rudest and simplest construction. Many of Boyle's experiments were performed with a few glass tubes and a syringe! Yet the results obtained were very tolerably accurate, and many completely so. Up to a certain point, in fact, and especially in chemical investigations, costly and complicated apparatus is not essentially necessary. For much depends upon the observer's own faculties of perception and combination. But beyond this the philosopher becomes to a very large extent dependent upon his instruments; and if these are not accurately constructed, he may be led to the most erroneous conclusions, and his inquiries merely result in the accumulation of a mass of inaccuracies. Not very long since a series of elaborate experiments were, after the expenditure of much time, brought to an unsuccessful issue, entirely in consequence of a defect in

their hands. Though the invention of the balloon dates long subsequent to this period, the germ of the idea appears to have come to light in some of their researches, for we find in one of their entries an account of glass-balls or bubbles rising in a heavy or condensed air, and falling in a lighter or more rarefied. The production of various gases was a frequent experiment, and they obtained among others the valuable result, that water actually dissolves air, which is expelled by heat, or by Mr. Boyle's instrument for the exhaustion of air—the air-pump. A number of excellent experiments on artificial respiration were successfully performed. The necessity of pure air for respiration was also shown, and the fact that respiration can be carried on without inconvenience in air much more condensed than the ordinary air we breathe. They endeavoured also to ascertain the capacity of the human lungs for air, and the expulsive power of the muscles of respiration. Dr. Wilkins performed some curious experiments before them, blowing up large weights by his breath. Their attention was likewise directed to meteorology; and an ingenious and excellent anemometer, or measurer of the force of the wind, was constructed, and its indications carefully studied. They performed a number of experiments also upon fluids. The solution of various salts, the temperature, pressure, expansion, and condensation of water in its various states, engaged their attention. They constructed several barometers forty feet high, with water, oil, &c., for the fluids. They also obtained interesting results upon the phenomena of capillary attraction. Among other of their experiments, it is interesting to record that 'of forcing water out of a vessel by its own vapour:' one of the early evidences of the motive power of steam. Magnetic experiments were also tried by them. The variation and dip of the magnetic needle, and the lifting force of natural and artificial

one of the instruments necessary for their prosecution. The insensitiveness of a chemist's balance, the defective construction of a lens, the incorrect graduation of a thermometer, or the faulty subdivision of the circle of a transit instrument, cannot but vitiate all researches in which they are employed. The accuracy and skill, therefore, with which a philosophical instrument is constructed, becomes of the highest importance to the advance of scientific truth. And that physical science in the present day has attained its present eminent position, and is still progressing, must be in a large degree attributed to the wonderful care exercised, and the mechanical skill displayed, in the production of philosophical instruments. What could have been done by astronomy, or in the knowledge of the barely visible world, had not the achromatic combination of lenses

magnets, were all inquired into. A number of botanical experiments were also performed. They proved the necessity of air to the germination of seeds, and tried whether plants would grow topsy-turvy, in order to find whether there were any valves in the pores of the wood, which opened only one way. A number of interesting physiological experiments were also made by them. Eggs were hatched; animals strangled, and brought to life again by artificial respiration; the fable of the spontaneous origin of life exposed; the effects of poisons on various creatures were noted; transfusion was tried; and a variety of experiments, which of late years have been repeated, of injecting various liquids into the veins of animals. A number of experiments were also made upon the phenomena of light, sound, colours, the laws of motion, &c. Their chemical experiments, consisting chiefly of distillation, evaporation, solution, and crystallisation, were instructive. Among other notable things examined, was, the mucilaginous matter called '*star-shoot.*' Optical experiments were also made. A variety of anatomical discoveries were communicated. It is unnecessary to swell the list; but it is apparent from this succinct account of their experimental labours, that if children in knowledge, our philosophers were men in energy and perseverance. In the short time that the New Philosophy had been at work, a greater mass of facts had been collected together than in a whole century prior to this era. Some of their experiments appear, and in truth they were, childish, but others have yielded both sound and solid information to succeeding inquirers. It appears that even in their day the utilitarian was accustomed to utter his provoking inquiry—*cui bono?* But the philosophers, remembering the advice of Lord Bacon, that there ought to be experiments of light as well as of fruit, disregarded the inquiry, and set themselves manfully to the task they had begun."

been invented? Constructed on the old principle, the telescope and the microscope only gave the most faulty and erroneous information; but as they are now made, they yield truth to the inquirer.

The subject of our present chapter has, therefore, an obvious and important connexion with the state, progress and prospects of philosophy. Nor must it be supposed for a moment, that the condition of physical philosophy is not intimately related to the well-being and advancement of social life. Few causes operate, in fact, so powerfully upon the civilization of a people as the prosperity of physical science. To it are we indebted for the steam-engine and the electric telegraph,—inventions originating entirely in physical philosophy, and exerting in their present almost infancy, the most wondrous and powerful influence upon the well-being of the human race. In the commonest objects around us, physical science has had its influence. The very paper upon which these words are impressed, was prepared for use by chemical science. Without pressing the inquiry further, it is apparent, from these considerations alone, that many of the interests of mankind are involved in the perfection of physical science, and as a necessary result, in that of the means by which the truths of that science are developed,—or, in other words, the instruments of philosophy.

We cannot hope, in the necessarily limited space of the present chapter, to notice many interesting and valuable philosophical instruments. So large is the subject, that many volumes would be occupied in its full consideration. We shall, therefore, select such departments of science as relate to light, heat, the electric fluid, chemistry, &c., and briefly notice a few instruments under each.

Commencing first with light, we may examine the instruments by which the illustrations appearing in this

volume were originally produced. The art of photography, or of producing pictures by sunlight, is of very recent introduction, for in 1851 the great inventor of one of its most interesting branches, died. Not many years ago, a lady in great distress applied to a philosopher about the mental state of her husband. He was declared to be in a state of approaching insanity, for the idea had taken full possession of his mind that he could produce pictures by aid of the sun, without assistance from any human artist. The fears of this lady, who was the wife of M. Daguerre, were presently stilled, and in a short time she had the gratification of witnessing the realization of her husband's conception, in beholding on the polished surface of a silver plate, the first sun-picture, whose lines so delicately drawn, and shades so harmoniously combined, at once impressed the observer that a greater artist than man had there been at work.

Messrs. Niepee and Daguerre had both been prosecuting their favourite idea for some years before they attained a successful result. Ultimately it occurred to Daguerre, to prepare a silver plate so as to be sensitive to light, by highly polishing its surface, and then producing upon it a delicate film of iodide of silver, by exposing it to the vapour of iodine. The plate thus exposed soon changed its colour, and became in succession yellow, red, and then of a blueish cast. It was placed in a camera-obscura, and the picture thrown ordinarily upon the ground glass was permitted to fall upon its surface. The impression was thus produced, but its effects were not visible on the plate. To bring out the impression it was found necessary to expose the plate to the vapour of mercury, which in a few minutes developed the picture in beautiful gradations of black and white. Such was the Daguerreotype as it left the hands of its inventor; an art of wondrous and almost

magical effects, but at that time in its mere infancy, and therefore very imperfect in its results. Future experimenters completed what Daguerre had commenced, and the art has now arrived at a very high state of advancement; and it is with peculiar interest that we here refer to it, since both in this and other works by the writer, it is to this art that we are indebted for the most truthful representations of the objects depicted.

The operations of the artist in proceeding to take a daguerreotype picture, may now be shortly described. The first consideration is to procure the camera obscura and lenses, and to adjust these for the purpose in view. The camera differs in many respects from the ordinary one used merely as an ingenious toy, or from the larger kind employed as an exhibition. It is a well made, square, mahogany box, in front of which the lens is attached. The back is, however, made to slide in and out of the front half; in the back of the camera is placed a small frame containing a piece of finely ground glass, and by advancing the back of the camera, or by withdrawing it, the picture on the glass is placed in focus, that is to say, is made to appear bright and sharply defined, just as we adjust a telescope to the object we desire to behold. The back is also fitted with a set screw, which holds it down at any particular distance to which it may be pushed; in the groove which receives the ground glass frame (or focussing frame,) other frames also fit which are called slides, and these frames are made so as to hold the daguerreotype plates, and are so accurately fitted, that when the slide is put in, the plate which it contains is precisely in the same place as that occupied by the ground glass, so that the same picture which fell upon the glass, can fall upon the plate. In order, however, to keep the plates from the light until the time when the picture is to be taken, a

sliding shutter is arranged in front, which can be drawn up and down, and in this way admit the rays of the picture to fall on the plate, or exclude that, and all other light, at the operator's pleasure.

The camera is generally made by a cabinet-maker, and although an important instrument in photography, is of much less consequence than the lens. The construction of the lens demands a high degree of skill, and for a long time the best lenses were only to be procured from one optician at Vienna—Voigtlander. Although much advance has taken place in the manufacture of these glasses, we are still disposed to give the preference, at least for rapidity of action, to the beautiful lenses made by Voigtlander. We have employed lenses made by almost all the eminent opticians, but have never found any which really equalled those of Vienna; these lenses were exclusively used for the photographs prepared for this volume.

A single and a compound lens are used in this art. The single lens is an achromatic glass, formed in fact of two lenses, on the principle of achromatism—which will on another occasion be noticed. It is, however, called a single lens, in contradistinction to the compound, which consists of two such lenses, mounted in a brass tube, one at one end, and the other at the opposite. The single lens is also mounted in a brass tube. By means of rack-work and a pinion, the lens can be moved in and out so as to focus the picture to a great degree of nicety on the ground glass. The single lens is generally used for views, and the compound for portraits. Whichever lens is used, it is screwed on to a plate in front of the camera, and is ready for work.

The camera is now complete, and it will be observed that it consists essentially of the lens, the focussing glass, or movable back, and the frame in which the prepared plate is to be laid. The camera is generally

placed upon a tripod, and adjusted to the object. We will now suppose a person to be seated for his portrait; he is placed in a chair in the open air, or in a room covered with glass, so as to cast as much light as possible upon him; the camera is then brought out and adjusted, the focus is taken, and the prepared plate is now to be brought. But let us see how it is that a flat silvered surface can be made so wondrously sensitive to light, as to retain the minutest detail of the figure, and individualize the very hairs of the head. The plate is of copper, and is covered with silver, either by the electrotype process, or by the ordinary way of plating. Great care is taken to have its surface beautifully clean, and finely polished, by first rubbing it over with cotton wool and moistened tripoli, and afterwards finishing up with the softest leather and rouge; in this way a mirror-like brilliancy is given to it, but it is as yet insensitive to light.

In order to render the plate sensitive the artist takes it into a dark room, the window of which is obscured with folds of yellow calico, for it is found that deep yellow light does not produce any effect upon the prepared plate. Here is placed a box, called a "coating box," in consequence of the chemical substances it contains having the property of giving a sensitive coat or film to the polished silver. The plate is laid, face downwards, over a porcelain pan, on one side of this box, which contains pure iodine. The result is, that it soon changes colour, and when it is of a rosy colour it is removed, and then placed over another pan which contains the chemical element called bromine, in combination with lime. Here the red colour slightly deepens; the plate is then again placed over the first pan for some seconds, and is now ready for use. It is by this apparently simple, but in reality delicate and difficult operation, rendered so wonderfully sensitive to the least ray of light, that it could not be passed rapidly even in

front of a key-hole without indicating that light had fallen on it in its way. The plate is now put into the slide, which fits into the camera.

Let us now return to the sitter. He is directed to assume a certain attitude, and, as far as possible, a natural and pleasing expression. The slide with the plate is then put into the back of the camera, the shutter is drawn up, the cap placed over the front of the lens is lifted, and in three seconds the impression is taken, the lens covered over, the shutter let down, and the first part of the operation is completed. But there is as yet not the remotest visible trace of a picture upon the plate; and in order to bring out the concealed impression it is taken again into the dark room; here the plate is taken out of the slide, and is placed in a second box, called the mercury box. At the bottom of this is an iron plate, upon which metallic mercury is placed; this is gently heated by a lamp, and the vapour rises and attacks the prepared plate. In a few seconds, delicate outlines of the portrait are seen, the white parts first, and at the expiration of a few minutes the whole becomes beautifully clear and distinct, until the most minute portions are shown. The plate is then removed, its surface cleansed, by being washed over with a chemical solution, and the picture is fixed so as not to fade, by a solution of pure gold, which effectually covers it, and, to a considerable extent, preserves it from tarnishing. The portrait is then finished, and being mounted in a case, the sitter is then dismissed with his counterpart in his pocket, the whole process having been completed in about ten or fifteen minutes.

But it may be asked, in what way can pictures be taken in the open air, and at a distance from the dark room and apparatus therein contained? The reply to this would lead us to greater length of discussion than might be suitable in the present work. It may, however, be

sufficient to state that many of the pictures which illustrate this book, were prepared by a peculiar process, which enables the artist to dispense with much of the cumbrous arrangements in ordinary use. By this process it is not difficult to leave home with a number of prepared plates, and to return in some hours after, with the pictures impressed upon their surface.

Photography on paper differs in many important respects from that on silver plates, and is now generally called Talbotype, as the latter is called Daguerreotype, after the name of one of its inventors, Mr. Fox Talbot. At a very early period, it was noticed that one of the preparations of silver turned black, when exposed to the light: but no attempt was made to use this as a means of obtaining pictures by light until long after. Several philosophers had their attention directed to this subject, and among others the Rev. J. B. Reade actually anticipated the most important of Mr. Talbot's discoveries. The latter gentleman, however, prosecuting an independent path of investigation, completely succeeded in procuring pictures by light, and took out a patent in the art. Facts have recently been published, which go to demonstrate that this patent was virtually invalid when granted, and that much though Mr. Talbot has done for photography, he has no just claim to several parts of the process which he asserted to be his own; in any case, it was an injudicious and ungenerous proceeding, and public opinion has often condemned it. Just as Mr. Talbot's patent was expiring, he gave up that part of it relating to views to the public, but still maintained his assumed exclusive right for portraiture.

The Talbotype requires the same instruments as the Daguerreotype, as far as regards the camera and lens; the slides are, however, slightly different, in order to fit them for holding paper instead of plates. The following is the method for taking a Talbotype picture. A sheet

of good paper is taken, and covered with a solution of nitrate of silver, and is then dried in the dark; the sheet when dry, is then covered with a solution of iodide of potassium, and is then washed and dried. This latter substance decomposes the nitrate of silver, and forms iodide of silver on the paper; paper thus prepared is not as yet very sensitive to the light, but by adding another application to its surface, it is rendered extremely susceptible of the most delicate rays. A solution of gallic acid in water, and a solution of nitrate of silver in minute proportions are used, diluted with water, to cover the surface of the paper, and when this is effected, the paper becomes very sensitive to light, and is said to be excited. If it be now exposed in the camera, an impression will be quickly made on the paper, but, as in the daguerreotype, it will not become visible until developed by an after process. This process consists in applying another mixture of gallic acid and nitrate of silver in solution, and in a few minutes the picture begins to appear, as if by magic, the white surface of the paper becoming covered over with houses, trees, and fields, as though some invisible pencil were swiftly tracing them upon it; this goes on until all the picture has come out; the paper is then well washed, and its chemicals removed by a solution of a salt called hyposulphite of soda.

But this picture is a "negative." How disappointed would that person be, who on first seeing the outlines of the scene, would expect to see the sky white, the trees dark, and the foreground darker still. He would see the very opposite, the sky black as ink, the trees whitish, and the foreground nearly white! A "negative" is a good term for such a picture, for it is the very negative of nature—the very opposite,—what is white in nature is black here, and the reverse. But in reality this is an immense advantage, for this negative can be made to

produce hundreds of pictures, in which the sky is white as in nature. This, then, is a further process in the Talbotype.

In order to produce a picture with the lights and shadows as in nature, paper is prepared by being washed over with a solution of common salt, and then dried. Afterwards, it is washed over with a solution of nitrate of silver and ammonia, and again dried. By this means, a decomposition is effected on its surface, producing a very sensitive compound of silver, the chloride. Now the negative is taken, and laid face downwards upon a sheet of this newly-prepared paper, and being squeezed close by a sheet of plate glass, both are exposed to sunshine. The brilliant light shining through the negative, produces its impression on the prepared sheet, and where the negative is black, underneath those places the other will be white, and the reverse. Thus, by a beautifully simple way, a positive picture is produced, in which all the lights and shadows in the most harmonious gradation are represented as in nature. When a sufficiently deep picture has thus been procured, it is taken and washed, and all the salts removed from it, and is then dried, and may be kept for any desired length of time. The same negative will produce many hundred pictures, and it thus becomes as valuable as an engraved block of wood, from the surface of which many impressions in succession are capable of being taken.

Very great progress has recently been made in the Talbotype. None of the recent improvements is more important, and none more beautiful than what is called the Collodion process. It is very generally known, that gun cotton will dissolve in ether, and form a very remarkable fluid, which, on being poured on a glass plate evaporates rapidly, and leaves behind a delicate film finer than the finest tissue paper, more delicate, in fact, than the membrane of the wing of a fly. It has occurred to several

persons, to use this substance in photography, and after a good deal of care, a most exquisite process was found out, which promises to leave the Talbotype and Daguerreotype far behind. The method alluded to, consists essentially of the following particulars:—A thin solution of gun cotton, in sulphuric ether, called collodion, is first obtained, and in every ounce of this, are dissolved three or four grains of iodide of potassium; some plate glass is now prepared, in sheets of a size suitable for the slides of the camera, and is very carefully polished. In a trough of gutta-percha, a solution of nitrate of silver is placed, and a flat piece of glass is provided, by which the sheet of plate glass can be plunged into this trough. The plate of glass is then taken in one hand, and the collodion is poured on it by the other; the superfluous collodion is then drained off at the corners, and the glass plate is now at once put into the solution of nitrate of silver in the trough. In a few minutes, the surface of the plate is covered with a most delicate film of iodide of silver, and the plate is now extremely sensitive to light.

The prepared plate is now hastily put into the camera slide, and the picture is taken. So wonderfully rapid is this process, that pictures have been taken in a fraction of a second, and representations of objects *in the act of falling*, have been produced. The curl of a wave before its fall upon the shore has been obtained in a collodion picture! The plate is then taken into the dark room, and being removed from the camera slide, is placed flat with its surface of collodion uppermost. A solution of sulphate of iron, or of an acid called pyro-gallic acid, is now poured on it, and in a few seconds the picture faintly appears, and in a minute or so it is completely developed. The plate is then washed with water, and with the hyposulphite of soda, and is finished. But this is also a negative picture, and, in order to obtain positives,

it must be laid upon prepared paper, as with paper negatives. It is, however, a very wonderful feature in the collodion process, that it is capable of producing positive pictures as well as negatives, and these are almost equal in delicacy to the finest daguerreotypes. In order to produce positives, a little alteration requires to be made in the time of exposing the picture, and also in the strength of the solution used to bring it out. The collodion process is rapidly coming into use for portraiture, and is admirably adapted for it, in consequence of the wonderful rapidity and delicate finish of this method.

The stereoscope, an instrument invented in 1837 by Professor Wheatstone, has received in the progress of the art of photography the most beautiful applications. It is generally known, that by means of this instrument the idea of solidity is given to the eye from pictures on flat surfaces. The principle upon which this instrument depends is thus explicable. When a house or a landscape are looked at, they are found to possess a quality which no copy on a flat surface by the best artist can produce. This is solidity or distance, the appearance of objects standing immediately behind each other. In using the term solidity, it should be borne in mind that distance is the same thing, since solids are only made up of the relative distances of parts of a single object. In perceiving this quality, the eyes separately receive a picture of the same objects, the one picture being a little different in perspective from the other, in consequence of the difference in the relative position of the two eyes. One eye, in fact, sees a little more round one side of an object, while the other sees a little more round the other side; and it is the combination of these two pictures by the faculty of sight that gives to objects their solid appearance.

Now, in order to obtain the same effect from a

picture, the stereoscope is so arranged, that two representations of the same object, the one slightly differing from the other, in perspective, are placed at the bottom of a little box, where an opening is made through which they are illuminated. At the upper part of the box are two small eye-pieces adapted, one for each of the observer's eyes. Through these he looks at the pictures, and the appearance of solidity is received in a very remarkable manner. It was found very difficult to draw pictures with sufficient accuracy to give good stereoscopic views, since a slight error in perspective would, to a certain extent, vitiate the resulting impression on the eye. But the photographic art supplied this want; for by taking two pictures with the camera first in the position of one eye, and then removed to a little distance to that of the other, this result is perfectly obtained without any risk of error.

The most lifelike representations of objects, of persons, groups, and even scenery, are now taken by professional photographers; and it is difficult to believe on inspecting these, that the real things or persons are not presented to the eye. Views of the Great Exhibition were taken, which reproduced it in all its solidity to the eye.

In January 1852, Professor Wheatstone read a second paper at the Royal Society, and exhibited an instrument which he calls a pseudoscope, on account of its giving false perceptions of all external objects. Some of the illusions were very extraordinary. Its effect may be briefly expressed as making whatever point is nearest seem farthest off, and *vice versâ;* so that all objects seen through it seem as if they were turned inside out. A solid terrestrial globe is seen concave, like Wyld's globe, with the map on the inside. The inside of a teacup appears a rounded projecting solid. A china vase, with embossed coloured flowers, appears

as if it were cut in two, and we saw the side with the flowers indented. A bust shows as a deep hollow mask. A framed picture hanging against the wall seems as if it were let into the wall; and in general objects placed before a wall are seen behind it, as if the wall were a mirror. Other more complicated, and in some cases perplexing, illusions are produced by the instrument, which is very portable.

There are many instruments connected with the practice of photography which are very interesting and ingenious in themselves, but are not of sufficient importance generally to deserve notice here. What is called the Focimeter is, however, so curious that it may be briefly adverted to. It is found that various lenses, and sometimes even the same lens, have not always the same focus. It is generally known that light consists of both chemical as well as luminous rays, and it is the chemical rays which produce the photographic impression. But the focus of the chemical rays is not in the same plane, in most lenses, as that of the luminous rays. Therefore the picture on the ground glass may appear very sharp, and yet the picture on the plate afterwards is very much blurred and indistinct. This is entirely in consequence of the fact just stated, namely, that the one focus is a little behind the other. Now it is obviously of great moment to the photographer to know the working of his lens in this respect, otherwise he could never succeed in obtaining sharp and well-defined pictures. To determine this, is the object of the Focimeter, for by its assistance the artist can immediately tell whether what is called the visual and the chemical focus are coincident. In all the lenses made by Mr. Ross, this defect is corrected by the relative adjustment of the glasses; but in the magnificent lenses of Voigtlander, of large size, this defect exists, and a scale is given on the tube of the lens by which it may

be easily corrected. It is, in fact, extremely difficult in such lenses as are made by Voigtlander, of very short focus, and large apertures, to make the chemical and visual foci absolutely coincident; it is, therefore, safer to know that the instrument works with a constant error, the amount of which may be learnt by the tube. In the smaller lenses of Voigtlander, the foci are coincident. It is, however, a remarkable fact, that the chemical and visual foci of the same lens differ slightly on different days, and hence arises a fresh source of perplexity to the photographer.

Let us suppose six small cards with the numerals 1, 2, 3, 4, 5, 6, printed on them, to be set perpendicularly on a piece of wood at a distance of three inches apart. Let the piece of wood be placed on a table with the card, No. 1, nearest the experimenter, and that No. 6, farthest from him. Now let him point his camera at this apparatus, and by moving the lens get a picture of card No. 3, sharp upon the ground glass. Then let him take a photograph of it on a daguerreotype plate. Now, if his chemical focus coincides, or falls on the same plane as the visual one, the portrait of card No. 3, ought to be bright and distinct, whilst all the others being at different distances would be blurred. If such be the result, his lens is correct (for the distance at which the experiment is made at any rate); but if not,—if instead of No. 3 being well defined, No. 5 is so, or No. 1,—then it is evident the chemical focus has not been in the same plane as the visual. Such is the principle of the focimeter, as it is generally made, and the annexed representation shows that of M. Claudet, in which the cards are set in a spiral around a horizontal rod of wood. There is another focimeter of somewhat different construction, in which the plate is made to take an inclined direction, so that the image falls upon it in an inclined plane; if, therefore, the object

focussed is not visible, sharpest on the middle of this plane, which represents the plane of the focussing glass, it will appear sharper either above or below it, and thus inform the operator where his true focus lies.

Photography has made the most surprising advances of late, and would doubtless long since have attained great perfection but for the existence of the two photographic patents, that of M. Daguerre and that of Mr. Talbot: so that those gentlemen who at first introduced this art, but then in a most imperfect condition, have done more to hinder its development (without any very substantial gain to themselves) than any other persons. There is now a Photographic Society, and a Photographic Journal. Very remarkable indeed are some of the recent feats of photography. Pictures of the enemy's castles, forts, and batteries, have been taken from the deck of a steamer going at the rate of ten knots an hour! The falling of the canvas covering of a statue has been caught in the very act. A picture has been taken by the electric flash of instantaneous duration; and a trace of the path of a ball from a rifle has also been obtained. These are marvellous results, and they show us how little an idea we are able to form of the future development of an art, when we contemplate only its beginnings,—for some of M. Daguerre's earliest portraits took half an hour and upwards for one sitting!

The telescope and instruments allied to it must now

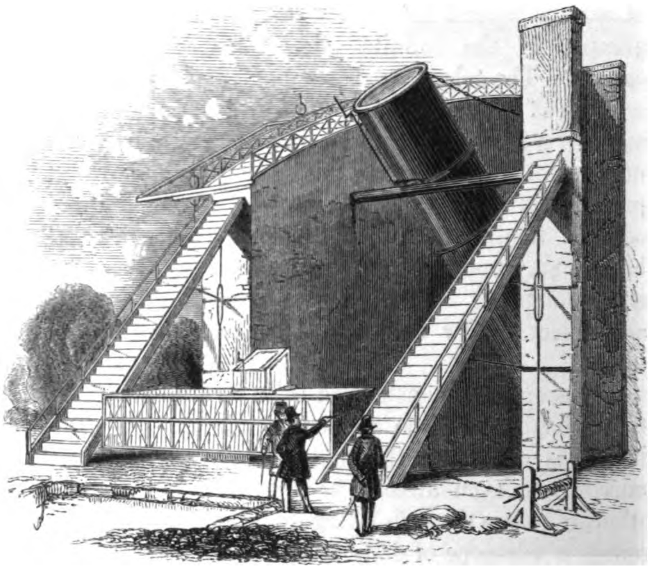
form the subjects for our notice. It may be said of the telescope and microscope, that they are man's aids in contemplating infinity. Himself occupying the middle position, with the one he looks at the infinite cloud of worlds beyond his own, with the other he catches a glimpse of the infinite microcosms within his own sphere. The telescope shows us God's greatness in the creation of mighty worlds, suns and stars,—the microscope His greatness in the formation of minutest beings, millions of which surround us, and live and die at the pressure of our feet. The history of the telescope is of such familiar knowledge that it is needless for us here to stay upon it. We shall, therefore, describe the construction of one of the best modern instruments, and select a few examples of such instruments now in use.

Telescopes are constructed upon two great principles, the reflecting and the refracting. In the one case, the image is caught in the first instance by a reflecting mirror, and then directed to the observer's eye; in the other, it passes through a large achromatic lens, as in the common telescope of daily use.

The great telescope of Lord Rosse may be taken as a magnificent example of a reflecting or Newtonian telescope. Professor Airy has so lucidly and admirably explained this great apparatus, together with the beautiful instrument of Mr. Lassell, of Liverpool, in a lecture delivered before the Astronomical Society, that we shall transfer the substance of his observations to our own pages:—

"Lord Rosse's Telescope is a wooden tube, its interior diameter exceeding 6 feet in every part, being at the middle about 7 feet, and nearly 50 feet in length. This is fixed to a cube of 10 feet, which has folding doors on that side which, when the telescope is horizontal, is the upper side (at which side the fixed frame supporting the

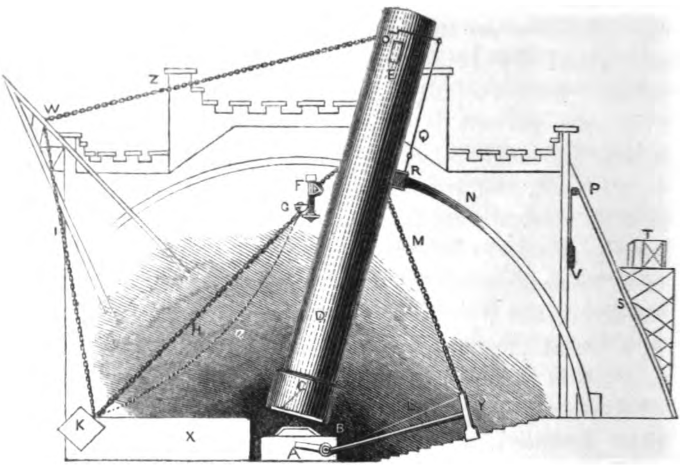
mirror is introduced, as has already been said), and which carries the fixed frame by three large screws in that side of the cube which is opposite the mouth of the



telescope. To this side of the cube is attached the universal joint by which the lower end of the telescope is connected with a fixed support, the joint being a few feet below the general surface of the ground. On each side (east and west) of the telescope is an enormous pier of solid masonry, about 70 feet long, in the north and south direction, between 40 and 50 feet high, and in its thickest part nearly 20 feet thick. [None of these dimensions are taken from actual measure.] The fixed support is nearer to the north than to the south ends of these piers. Near the top of the pier, on the interior faces, in the east and west plane passing through the universal joint, are two cranes with pulleys (the turning

crane being no bigger than suffices to carry a large pulley, whose edge is in the vertical action of the crane); over these cranes the chain passes which are attached to the telescope; and to the lower ends of the chains, after they have passed fixed pulleys on the walls, are attached the counterpoises, weighing about four tons each. These counterpoises are not allowed to depend freely, but are connected by bridle-chains with wooden horns that project from the north ends of the piers; the effect of this arrangement is, that when the telescope tube is nearly horizontal, and the force required to support it is very great, the weight of the counterpoises acts very nearly vertically on the chains, and is entirely effective for the support of the telescope; but when the telescope is considerably elevated, and less supporting force is required, the weight of the counterpoises is supported in a great measure by the bridle-chains, and very little tension is given to the supporting chains. For the sake of supplying some slight defects in the laws of tension thus produced, and also for the sake of constantly producing a small tendency in the telescope towards the south horizon, other counterpoises, in a pit south of the fixed support, are brought successively into action as the telescope is raised. There is then only a comparatively small and very manageable tendency of the telescope towards the south; and this is supported by a light chain which passes over a pulley on a bar connecting the horns before mentioned (the pulley being in the direction of a polar axis passing through the lower universal joint, and the motion of the telescope, therefore, for a given length of the chain, being equatorial); and this chain is shortened or lengthened, and the telescope is thereby raised or depressed, by a windlass a little way north of the fixed support. Upon the inner face of the eastern pier is an iron arc of a circle, upon which slides a runner connected with a rod that passes through a frame on the

telescope tube and near to its mouth, and is there racked for working with a pinion. By the movement of this pinion, the distance of the telescope from the pier is altered, and thus a motion in hour-angle is given. At



the south ends of the piers there are strong ladders, upon which (assisted by counterpoises) there slides a stage; upon which stage a small observing-box travels east and west: this is used for observing, so long as the mouth of the telescope is below the end of the pier. For great elevations, the top of the western pier being shaped by slopes so as to approximate to a circular arc, there are mounted upon it curved galleries, which are carried by beams that run above and below pulleys fixed to the top of the pier; and the galleries are carried out by rack-and-pinion work, to approach the side of the telescope. It is intended to give the power of observing as far north as the pole; but at present the galleries only extend to the zenith. The telescope is Newtonian,

the minor axis of the small mirror being about six inches, and the observer looks into the side of the tube.

The engraving shows a view of the inside of the eastern wall, with all the machinery seen in section. A is the mason-work in the ground; B the universal joint, which allows the tube to turn in all directions; C the speculum in its box; D the tube; E the eye-piece; F the moveable pulley; G the fixed one; H the chain from the side of tube; I the chain from the beam; K the counterpoise; L the lever; M the chain connecting it with the tube; Z the chain which passes from the tube to the windlass over a pulley on a truss-beam, which runs from W to the same situation in the opposite wall—the pulley is not seen; X is a railroad on which the speculum is drawn either to or from its box; part is cut away to show the counterpoise. The dotted line, *a*, represents the course of the weight R as the tube rises or falls: it is a segment of a circle of which the chain I is the radius.

With a little attention to these several points, the working of the machinery, we think, will be easily comprehended. The weight on the lever L sinks only 15 feet under the horizontal position; it then rests on the ground, and is, of course, no load on the tube, which is, when this happens, 30 degrees above the horizon. Below this point the tube is sufficiently heavy to descend when the windlass unrolls the chain. Then suppose the tube makes the angle of 30 degrees with the horizon, and that it is required to elevate it, the windlass is turned, and the chain being shortened, the desired effect is produced; but the labour of this would be immense if the counterpoise K did not assist; this nearly balancing the tube, leaves but little exertion to be made at the windlass. However, the weight of the tube, according as it ascends, is gradually becoming less and

less, until it produces no strain at all on the windlass when it is quite upright. This must evidently be the case from the first principles of mechanics; for, making the tube a lever, the length of its arm continually decreases as it approaches the perpendicular; therefore, if the counterpoise continued the same weight on the tube towards the end as it was in the commencement of the ascent, it would be too heavy, and would keep it in its perpendicular position. In fact, the counterpoise must become lighter as gradually and as evenly as the tube itself, in order to continue to be just the same support to it all through its movement. The plan adopted to effect this is beautifully simple: a weight hanging freely in a perpendicular direction, exerts its greatest force on the suspending point; if it be moved from the perpendicular, as much power as is required to effect this, is taken off from the same point; as will be evident to any person pushing aside a hanging body—he must supply a certain degree of force to keep it out of its perpendicular position. Now, it will easily be at once seen, how, when the tube is ascending and losing its weight, also lengthening the chain H, that on account of the chain I, whose length is always constant, the counterpoise K is moving from the perpendicular position under G, and therefore losing its power on the tube, and approaching the perpendicular under W, and for this reason transferring all its weight to the fixed chain I: when the tube passes the perpendicular, the chain H is again shortened, and the counterpoise once more begins to draw it back, so that the action of this tends to keep the tube always upright, to whatever side it may point, and its power is always equal to the varying weight. Under these circumstances, we see how easily and evenly the windlass can elevate the telescope, and turn it to the north: but when it arrives there it must be brought back again; and this is accomplished by the

lever L. As we have seen that the action of the tube and the counterpoise is so regulated, that in all positions the weights, although always changing, are equal to one another, so must the weight of the lever vary with its position in order to be a perfect balance on the tube; and this it evidently does. We said that when the tube was perpendicular, the weight on the lever is most effective; for it is at the furthest distance from the support that it can be; it therefore pulls down the tube when the windlass is unrolled: but we saw that the tube as it descends increases its weight, so that if the lever continued acting with the same power with which it commenced, the weight of both would be constantly increasing; this is prevented by the lever losing its force as it falls, for the weight thereby, of course, approaches the support, and cannot be so active; but the approach to the support by its descent is so regulated to the increasing distance of the end of the tube in its descent by the chain M, that in the same degree as the latter gains weight the former loses it; in this manner there is a constant equilibrium kept up between them. When the tube reaches within 30 degrees of the horizon the lever rests on the ground, and the tube is thence able to descend by its own weight. When the tube points to the north, the lever is elevated above the horizon, and has not, of course, so much power as when it coincided with it; but it is in this case helped by the counterpoise K, which always tends to bring the tube to the perpendicular. This continues to help it until it becomes itself sufficiently able, from its horizontal position, to do all the work; it then commences opposing it; but it has now the help of the increasing weight of the tube itself, and so all the parts are elegantly blended into one another with the most perfect concord and efficiency.

The tube is moved from wall to wall, by the rachet

and wheel at R in the cut; the wheel is turned by the handle O, and the rachet is fixed to the circle on the wall. The ladders in front, as shown in the large sketch, enable the observer to follow the tube in its ascent to where the galleries on the side wall commence; these side galleries are three in number, and each can be moved from wall to wall by the observer, after the tube, the motion of which he also accomplishes by means of the handle O.

Mr. Lassell's telescope tube is of sheet iron; and this tube is not carried immediately by the mounting, but is inserted in a long box of cast-iron, in which it can be turned round its own axis. This movement is necessary to place the eye-piece exactly in the same side-position in all directions of the telescope, and also to cause the edgewise support of the mirror to act always in the same way. The long bar is mounted equatorially, the polar axis turning in two bearings below the declination axis, and carrying an hour-circle, upon which are fixed two supports, in which turn the two pivots of the declination axis of the long box. The telescope is Newtonian, the eye-tube being in one side; but the smaller dimensions of the small mirror (a diameter of two inches only being required) enable Mr. Lassell to use the reflection at the internal surface of a glass prism, by which much more light is reflected than by a metallic reflector. At first much annoyance was caused by the disposition of dew on the glass; but this was remedied by attaching to it a case carrying a small piece of heated lead; and when proper attention is given to the inclosure of the lead, no inconvenience is sustained from the effect of the hot metal in disturbing the air in the tube of the telescope. The whole is covered by a revolving dome thirty feet in diameter, and the observer is mounted for observation on a stage which is carried by the dome."

A very beautiful example of a refracting telescope was exhibited in 1851 by Mr. Ross. The object-glass of this splendid instrument was eleven inches and a half in diameter, and at the time it was considered to be one

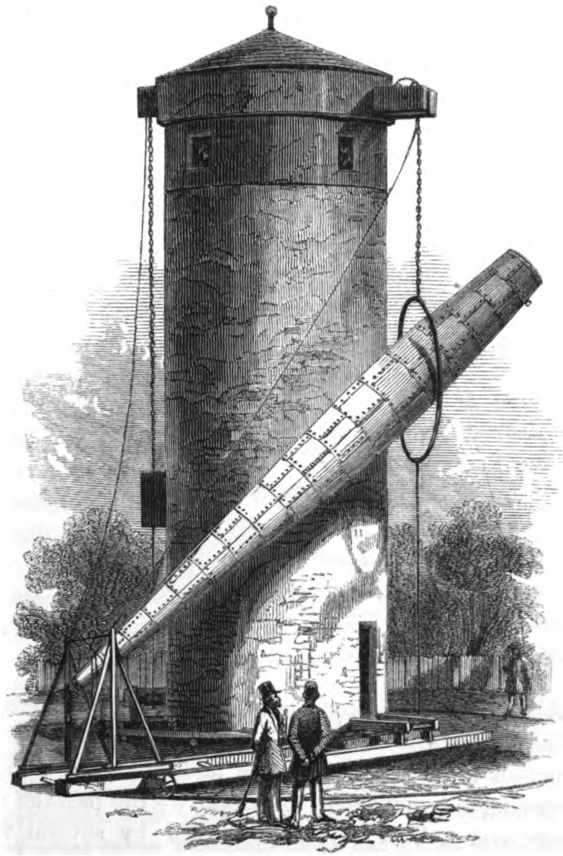
of the largest and most powerful achromatic telescopes ever constructed in Great Britain. A magnifying power of six hundred times in diameter could be used in this instrument, without prejudicially darkening the field of vision. The telescope was mounted on an iron pillar,

on the top of which was an adjusting arrangement by which the instrument might be pointed to any part of the heavens. In this great equatorial (see cut), Mr. Ross has followed the example of the Astronomer Royal, by having every part of the instrument cast in as few pieces as possible, and thus has avoided all unnecessary screw connexions. The casting of the metal work of this telescope was a fine piece of solid and accurate workmanship.

Another and smaller instrument by the same maker was a refracting telescope of 3 feet focal length and 2½ inches aperture. This telescope was examined by the jury on test objects at 150 yards. These consisted of two black marble balls, highly polished, placed in full sunshine, a watch dial, and small balls of white ivory on a black ground. On using the telescope upon these, it was found to perform well, giving well concentrated images of the artificial stars produced on the marble balls, with but a small trace of uncorrected colour.

Very large refracting telescopes have been used at Pulkowa and in the United States. The diameter of the object-glass of one of these instruments is nearly 16 inches. A very large telescope has also recently been constructed by the Rev. Mr. Craig, on Wandsworth Common. The arrangement of this instrument is as follows:—There is a brick tower 64 feet in height and 15 feet in diameter, with a long tube slung at its side. This tube is the telescope. It is 76 feet long, and is shaped somewhat like a cigar. The circumference of the tube is 13 feet at its greatest diameter. The glasses are of plate-glass and of flint. The tube rests upon a wooden framework, with iron wheels attached, and is fitted to a circular iron railway, at a distance of 52 feet from the centre of the tower. A little force applied to the wheel on the iron rail causes the instrument to move

horizontally round the central tower, while a wheel at the right hand of the observer enables him to elevate or depress the object-glass with precision and care. A



popular notion of the magnifying power of this instrument is conveyed by the statement, that by it a quarter-inch letter can be read at the distance of half a mile.

Some good telescopes were sent by the French makers, and that figured in the cut was thought worthy of meritorious notice by the Jury. The stand is strong and steady.

Allied to the telescope is the astronomical instrument called a Transit Instrument. It is in essential construction a telescope with the addition of a means of observing the movement of a star by the passage of its image over a field of vision crossed by several wires. An observation with such an instrument consists in directing the telescope so that the star is bisected by one of the wires which is horizontal, and then noting the times at which it passes the vertical wires. These times are determined by mentally dividing into ten parts the

space traversed by the star in one second, and deciding that tenth of the second when it crossed the wire. These wires, however, cannot be seen at night when searching for stars, and therefore it becomes necessary to throw artificial light into the telescope in such a way as to illuminate the wires without drowning the light of the star. This is accomplished in a most ingenious manner by using a lantern, which is placed at the hollow pivot of the instrument, and the light of which is reflected upon the field of view by a reflection within; this reflection in Mr. Simms' beautiful arrangement is movable, so that a very intense or a very subdued light can be thrown upon the field of view. In another of this eminent optician's arrangements, the reflector is connected with a prism, which is so adjusted that when it is required merely to illuminate the wires, the reflector is thrown out of action; and when it is necessary to illuminate the whole field of view, then the prism (which merely casts light horizontally over the wires) is thrown out of action. In this way the faintest star can be discerned, and its movement recorded without any obstacle from the redundance of artificial light. By this admirable arrangement, comets, nebulæ, small planets and stars, which are visible only when all light is excluded from the field of the instrument, and when the wires alone could be illuminated, become perceptible.

Another very remarkable modern improvement in the transit instrument consists in the ingenious American invention of using the galvanic circuit for registering observations. In ordinary transit observations, the astronomer takes a second from the clock face, counts the beats whilst the object crosses the wires,—records these times by the clock to the tenth part of a second,—writes them in a book, still counting the beats of the clock; and after the transit of the last wire, continues

counting on till he can look at the clock face. But by the new method, the coincidence of the wire and the object is noted, at which instant a key is touched with the finger, and an impression is instantly made by the galvanic current upon paper prepared for that purpose. The utmost rapidity of action characterises this invention, and it is possible to take observations by it even to the hundredth part of a second. This apparatus is in use at the Washington Observatory, and was exhibited in 1851 by Mr. Bond, the American astronomer.

In order to keep the instrument fixed upon the object to which it is directed, so that it should not be moved on by the motion of the earth on which the observation is being taken, a very ingenious arrangement has been introduced. It consists of a clock-work motion so adjusted that the motion is transferred to the telescope in such a way as to counteract the movement of the earth. Thus, while the earth is carried by its revolution toward the east, the telescope is moved toward the west, and at such a rate as to oppose and neutralize the motion of the earth. It will be readily understood that in all prolonged examinations of the heavenly bodies such a movement becomes very important. It was attached to Ross's great equatorial, and is supplied with all the best instruments of the best makers.

The divisions in all these instruments require to be cut with the minutest accuracy, and constituted until of late the most formidable part in the construction of a good astronomical telescope. The Great Exhibition contained a remarkable specimen of such divisions in the circle of the far-famed Westbury instrument. These circles, it may be premised, are generally divided by hand, and extreme skill and care are necessary in the task. The production of the two circles of the Westbury instrument occupied Mr. Simms nearly twelve weeks, of

six days in each week, and on an average of eight hours every day! The work was performed by lamp-light, in a room otherwise completely darkened, and it proved, as may well be imagined, a most anxious and oppressive task. Mr. Simms was ultimately led to the invention of a machine, by which this difficult and delicate labour can be performed with unerring accuracy, and with the most wonderful economy of time. This apparatus is a self-acting dividing-engine, by means of which the same work, which formerly occupied from five to six weeks, is accomplished in as many hours. The Great Transit Circle lately erected at Greenwich Observatory, was divided by this ingenious machine.

The microscope, opening up to our view the wonders of the world in which we dwell, is scarcely less interesting as a philosophical instrument than that which we have just considered. What the telescope has accomplished in penetrating the universe of worlds, this instrument effects in the aid it affords to our investigations into our own world. The geologist and the naturalist recount, by its assistance, as many marvels as the astronomer with his telescope. It would be entering into the mere elements of natural philosophy were we, in this place, to advert to the optical principles involved in the construction of the microscope in all their detail. We shall only, therefore, advert to two circumstances connected therewith, and the comprehension of which is necessary to that of this instrument. The first of these is what is called the spherical aberration of lenses, and the second, the chromatic aberration. By spherical aberration, it is meant that the rays of light do not all meet exactly in the same plane. The central rays, for instance, may be in focus, while those passing through the circumference of the lens are out of focus. The other term, chromatic aberration, refers to the result of the unequal refrangibility of the coloured rays which, when combined, form white light. The

coloured rays are not all brought to the same focus, even by a lens which is corrected for spherical aberration; hence the fringe of colour seen when looking through a non-achromatic microscope.

In order to correct the spherical aberration of a lens, it has been found that the rays may be brought into one focus by a modification of the form of the lens. The form best calculated to effect this is a lens whose section is an ellipse or an hyperbola. In order, however, to correct the chromatic aberration, or to render the lens achromatic, a difference in the composition of two lenses, by which they act differently upon the rays of light, must be made use of. Now, it has been found that flint glass and crown glass have two distinct properties or effects upon the light they transmit, and these properties in the dispersion of the rays of light may be so combined as exactly to neutralize each other; therefore, by uniting two lenses, one of crown glass and the other of flint glass, the chromatic aberration becomes entirely mastered, and the rays are brought to one focus, quite free from all coloured rays. But, in addition to the chromatic aberration of the rays of light, there is also that of the chemical rays, which do not on passing through an ordinary lens, come to a focus in the same plane as the coloured rays. This focus is called the actinic focus, and is of the highest importance in a photographic sense. It is possible, however, to correct this, together with the spherical and chromatic aberration, by a carefully constructed lens, and Mr. Ross makes all the lenses he sells for photography on this principle.

The reader is now in a position to understand the right sense of the term achromatic, and also to judge of its importance in the construction of so delicate an instrument as a compound microscope. The microscope is either simple or compound. The simple microscope may consist of one, two, or three lenses, but these are

all so arranged as to produce only the effect of a single lens. In the compound microscope, not less than two lenses must be employed; one to form the inverted image of the object, and this, being placed nearest the object, is called the object-glass; the other lens is used to magnify the image of the object, and this, being nearest to the eye of the observer, is called the eye-piece. Both these lenses are achromatic, that is to say, they consist of two lenses united together, so that in reality the rays of light would pass through two pairs of glasses; the first pair forming the object-glass, and the second pair the eye-glass. The difference between a simple and a compound microscope amounts just to this, that the simple microscope magnifies the object itself, and transmits the magnified image to the observer's eye, whereas in the compound microscope, the magnified image is brought to a focus within the instrument, and is there magnified again by the eye-piece, after which it enters the eye. It may be added, also, that in the compound microscope, the object-glass may consist of one, two, or even three lenses. With these remarks upon the essential features in the construction of the microscope, it will not be difficult to obtain a clear idea of the various parts necessary to the practical carrying out of these principles.

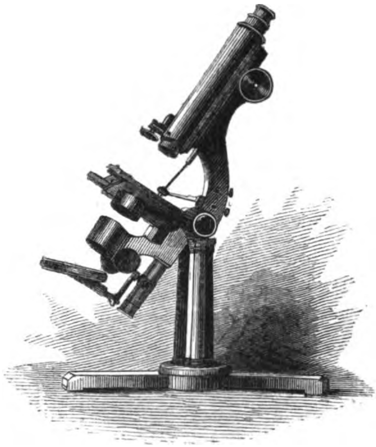
The most important feature in the construction of the microscope is to make it as steady as possible, and this is rendered extremely difficult, in consequence of the shape of the instrument. The best microscopes are constructed in the following manner: there is first a solid tripod base, made of brass, and tolerably heavy, so as to secure freedom from oscillatory motion as far as possible. Rising perpendicularly from this are two pieces of brass, which form one casting with the base, and, in the interval between these uprights, the microscope is carried. Between the uprights is an axis, upon which

the whole of the upper part of the instrument turns, so as to enable it to take a horizontal or vertical position, or any intermediate inclination. At this part, the moveable portions of the instrument are attached. There is the stage, upon which the objects are placed, and the arm, which carries the tube. In order to elevate or depress the tube, the arm is capable of being raised or lowered by a screw, and the optical part of the instrument can thus be brought nearer or further, as may be necessary for the examination of the object. An additional, but more delicate, screw is also attached to the tube, which answers the same purpose, and is called the fine adjustment. The stage has a variety of movements connected with it, by which the object can be placed in every required position. Below the stage the reflecting mirror is mounted.

Mr. Ross has long been justly celebrated for his splendid microscopes; and Messrs. Smith & Beck, and Messrs. Powell & Lealand are also the best makers of this instrument. The microscopes of Mr. Ross were awarded a Council Medal, and the same reward was made to Messrs. Smith & Beck. The instrument for which the latter reward was given is shown in the cut, and is thus described in the Juries' Report:—

"Smith & Beck exhibit a microscope, the stand of which in appearance is not highly finished, but their forbearance to expend time and money on elaborately finishing the non-working part has been adopted on the strong recommendation of some of the oldest naturalists in London, in order that students may acquire instruments with first-rate glasses at the least possible expense, and that such instruments may be brought within the compass of those whose means are limited. The stand is excellent in principle: the body, stage, and appliances beneath are all carried on one stout cast bar, on the recommendation of Mr. E. Jackson, by means

of which the centring of the achromatic illumination is rendered easy and certain, and on any tremor being communicated to the instrument, it is equally distributed over the whole of the working parts.



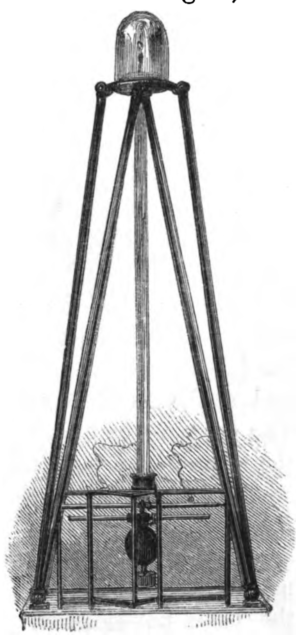
"The lever motion to the stage of this instrument is the most easy and generally useful that has yet been applied. If used with the right hand, while the quick and slow adjustments to the focus are worked with the left, there is no animalcule that cannot be readily followed, however fitful and rapid its movements; and any globule of blood pursuing its course through the most tortuous of the capillaries, can be steadily and easily traced, and every alteration of its form observed during its passage through these minute vessels. The field of view may also be swept horizontally or perpendicularly, and the most delicate micrometrical measurements made with great ease and precision. This stage is the invention of Mr. Alfred White; the rabbited groove on which the body moves was suggested by Mr. George Jackson, at whose recommendation the fulcrum of the stage movement was fixed to a spring, instead of to a rigid bar. The simplicity and efficiency of the whole of this stand are highly commendable. The half-inch focus object-glass of 70° aperture is a wonderfully fine combination, easily showing objects, considered difficult for a one-eighth inch focal length a little more than a year since, and bearing the application of the higher eye-pieces in an unprecedented manner."

We pass by a very interesting transition, from instruments connected with light to those connected with magnetism and electricity; for the beautiful apparatus we are now about to describe is set in motion by magnetism, and its movements are recorded by light. It is not difficult to imagine an arrangement by which clockwork may be made to record observations, for it is merely a question of mechanical skill, and is only applicable to particular cases where a mechanical force is concerned. But what apparatus could register the vibrations of a magnetic needle, tremblingly balanced from a silken thread, and by its very nature incapable of communicating movement to anything else? A more impossible task, as it might appear, could not have been devised. It has, however, been accomplished by Mr. Brooke, and the slightest quivering of the magnetic needle registers itself in unmistakeable lines on paper by the agency of light. We shall endeavour to make this apparent to the reader in the plainest way.

From what has already been stated it will be understood that the least ray of light falling on a piece of prepared paper will leave a trace behind, which will mark the circumstance in an indelible manner. Now, let us suppose a magnetic needle to have a mirror attached to it, which would reflect the light of a lamp on to a sheet of paper so placed that the direct light of the lamp could not reach it; we should then have a self-registering apparatus, for every movement of the needle would cause the mirror to cast a beam on the photographic paper, and this beam would leave its mark behind, and thus record the fact.

Mr. Brooke has applied this beautiful idea to the registration not merely of magnetic but also of thermometric and barometric phenomena. The paper is prepared so as to render it extremely sensitive to light, being first washed with a solution of isinglass, bromide of potassium, and iodide of potassium, in the

proportion of 1, 3, and 2, respectively; and when required for use, it is washed with an aqueous solution of nitrate of silver, which causes the paper to be sufficiently sensitive to the action of light, so that if a beam of light be allowed to fall upon it, an impression is made upon that part where the light falls, which becomes visible on being washed with a solution of gallic acid, with a small admixture of acetic acid. A light is placed near a small aperture, through which rays pass and fall upon a concave mirror carried by a part of the suspension apparatus of the magnet, and this reflection falls upon a plano-cylindrical lens of glass placed at the distance of its focal length from the paper on the cylinder. The cut represents the arrangement of the magnet, with its reflecting mirror. As the magnet is ever varying and making small excursions on one or other side of its mean position, the point of light traces a corresponding zigzag line on the paper. The thermometer apparatus has no mirror and no reflector, the mercury in the tubes themselves intercepting the pencils of light; and thus this apparatus, throughout the day and night, is constantly recording the slightest change of position of the magnets, and the smallest changes of temperature.



The self-registering barometer is constructed on similar principles, the rise and fall of the mercurial column actuating a small lever which carries a shade before the

light, and thus intercepts the rays which then impress the exposed part of the paper, while that which is covered receives no mark.

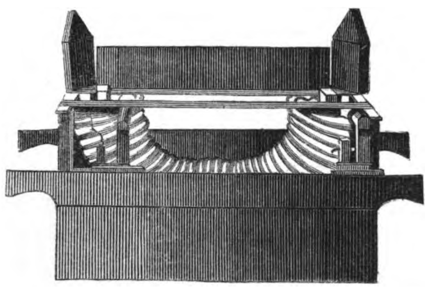
The common phenomena of magnetism are well understood by most persons, but great ignorance prevails as to the right construction of a magnet even by makers of these instruments, and, as a result, the most varied powers are obtained from magnets of the same weight, but formed on differing principles.

The Rev. Dr. Scoresby appears to have been the first to employ thin sheet steel for the construction of powerful permanent magnets. His idea being, that, as magnetism appeared to reside principally on the surface of the metal, by multiplying the number of surfaces, the power of the compound bar would be increased. Mr. Hearder, many years since, constructed powerful magnets from thin plates of cast-iron, and was certainly the first to use that material for the purpose; and the power which can be induced is certainly very great when they are fitted with soft iron caps.

One of his magnets was shown at the Exhibition. It consisted of 24 plates, 2 inches wide, $\frac{3}{16}$ of an inch thick, cast in the form of a horse-shoe, which is $16\frac{3}{4}$ inches long from the poles to the outside of the bend; the poles are $1\frac{1}{4}$ inches as under, and the inside of the bend $3\frac{1}{4}$ inches wide. The 24 plates weigh about 72 lbs., and are fastened together with three bolts and nuts. The poles are capped with soft iron, which concentrates the magnetic power in an extraordinary manner. The construction is very simple: the bars are cast from No. 1 pig-iron as hard as green sand can make them, and they require no preparation to adapt them for magnetization. The soft iron caps render the grinding of the poles unnecessary. The attractive power of the magnet is scarcely inferior to that of a steel magnet of the same dimensions, whilst the economy in construction

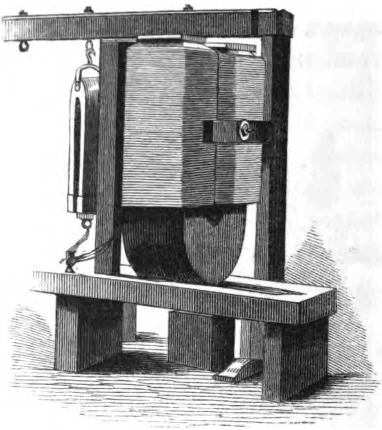
is nearly as 4 to 1; the cast-iron magnet weighing 72lbs., lifts 140lbs.

A powerful horse-shoe steel magnet was also shown, of 100 plates, adapted for purposes requiring high magnetic power. It weighed about 39lbs., and would support nearly 250lbs. with a round-faced keeper. But by far the most powerful magnets in the Exhibition were those exhibited by Messrs. Logeman, and these were of such extraordinary power that a Council Medal was awarded to the makers. A small magnet, weighing only 1lb. ½oz., carried the surprising weight of 16lbs. 9½oz.! Another, 101lbs. 12oz., carried a weight more than four times greater than its own, namely, 436lbs. 12oz.



The various phenomena exhibited by the magnetic needle are demonstrable by appropriate instruments, but it is not our purpose to consider these in the present volume. We may, therefore, pass on to the highly interesting subject of Electro-magnetism. We have already referred to this subject as applied to become a source of mechanical power; we shall now consider it as connected with the Electric Telegraph. Two very interesting electro-magnets made by Mr. Joule, and represented in the cut, deserve our passing notice. The first of these, shown in the cut, was constructed of a plate of well-annealed wrought-iron, tapered to the

poles. The iron is rendered magnetic by transmitting the voltaic electricity through the bundle of copper wire (50 yards long, and weighing one cwt.) with which it is enveloped. It was fitted with a pair of tapered armatures, shown in a perpendicular position in the cut, to concentrate the magnetic force when the electro-magnet is excited by a feeble voltaic current, and to direct the magnetic action to any required object. The other was called a surface electro-magnet, consisting of a thick piece of wrought-iron, enveloped by a bundle



of copper wires. A battery of moderate power produces such a powerful attraction between the electro-magnet and its armature, that a weight of more than one ton has to be applied in order to draw them asunder. The peculiarity of the latter, or surface electro-magnet (which is the first of the kind ever constructed), consists in the comparatively great surface of contact which it presents to its armature. The principle of its construction, and of that of others of its class subsequently constructed by Mr. Joule and other parties, is derived from the law of electro-magnetic action discovered by him,

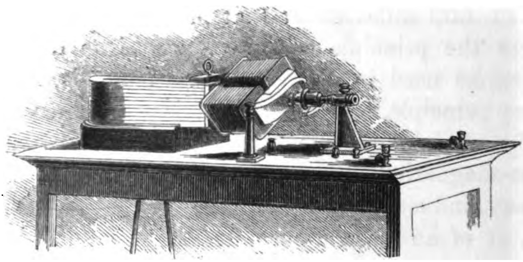
viz. that the maximum attractive power of an electro-magnet for its armature is about 300 lbs. for each square inch of transverse section of the magnetic circuit.

It is a singular fact, first discovered by Professor Oersted, that a magnetic needle placed within the influence of a current of electricity circulating through a coil of wire, has immediately a tendency to deflect, or turn aside, communicated to it, and a needle thus placed is called a Galvanometer, since the amount of its deflection represents, to a certain extent, that of the current passing through the wire. It is of no consequence where the needle may be placed, or at how great a distance from the source of electricity, for provided the battery be of sufficient power, and the wire properly insulated, the needle can be deflected as readily at a distance of 500 miles as at that of a few feet. In this consists the principle of the ordinary form of Electric Telegraphs used in this country. There is, however, another principle, also discovered by Oersted, which is equally available for telegraphic purposes. This is the electro-magnetic force just noticed—the magnetism, that is to say, induced in a soft bar of iron by the circulation round it of an electric current. Thus, by making and unmaking the magnet a series of signals can be transmitted as before to any distance. The telegraphs in the United States are made on this principle, and some in this country are also of this construction.

The most extraordinary variety of electric telegraphs have been invented since the first introduction of this wonderful instrument. A consideration of them at length would only occupy space without materially interesting the reader. We shall, therefore, discuss the subject of the electric telegraph under the following two heads:—1st. Telegraphs signalizing by needles; 2d. Telegraphs signalizing by printing or marking.

The Galvanometric Telegraph, in which a magnet in

the form of a needle is deflected by an electric current passing through wire, is, as before stated, the most common in general use in England. The force used to work this apparatus is generated in a galvanic battery of simple construction. It consists of a trough lined with marine glue, and filled with alternate pairs of zinc and copper plates; the galvanic current is excited by sand moistened with dilute sulphuric acid, and is carried off by copper wires attached to each pole of the battery. Another source of the current is what is called the magneto-electric machine shown in the cut. One of the best explanations of the cause of magnetism is, that the attracting power of the bar of steel, which we call a magnet, is due to the circulation of electric currents around the bar.



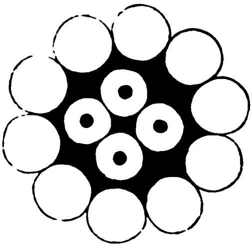
It was discovered by Faraday, that when a metallic mass is moved in proximity to the poles, a current is induced in it; and upon this principle magneto-electric machines are constructed. The soft iron armature, or keeper of the permanent magnet, is fixed on an axle, which is made to revolve by some mechanical contrivance, so that a continued and rapid reversal of its poles takes place (see cut). By this alone a magneto-electric disturbance is effected; but for the purpose of accumulating the force, coils of copper-wire are fixed on the armature, and every time they approach or leave the poles of the magnet in the course of rotation, an induced current passes through

the wire, and the reversal being extremely rapid, though the current is only instantaneous, the result is what may be regarded as an uninterrupted stream of electricity.

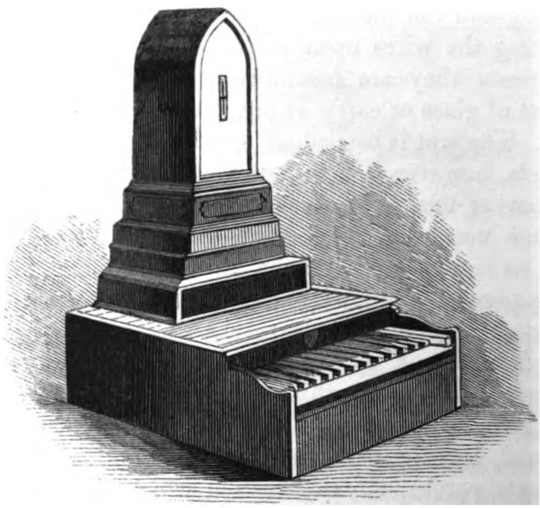
The magneto-electric machine was first employed for telegraphic purposes by Professor Wheatstone. The battery is however usually preferred in this country. The magneto-electric machine has the advantage of being of constant power, remaining for an unlimited time capable of generating the induced electric current.

It is found, in practice, that the wires have a great tendency to part with their electricity unless they are very carefully insulated. This is particularly the case in long circuits, and the wires would totally lose their electricity in the course of a few miles unless the utmost care was taken to prevent its passing off into the earth. In England the method adopted for effecting this is by carrying the wires upon posts. As the wires hang on the posts they are insulated from their supports by means of glass or earthenware, through which the wires pass. The wet is carried off by a little roof above. For tunnels, however, where there is much moisture, and for submarine telegraphs, some other means of insulation become necessary. A variety of substances have been tried as insulators, but none have been found to equal gutta percha. The wires are covered in the following manner: a mass of gutta percha in a soft state is contained within a cylinder, and being acted upon by a piston is driven out through a small die, in the centre of which is the wire. The latter being slowly drawn forward, becomes surrounded with an uniform covering of gutta percha, the thickness of which varies with the diameter of the die-hole through which it is compressed. The coated wire is then drawn through a trough of cold water and wound on a drum. Its insulation is afterwards tested by passing an electric current through it while under water, and observing the deflection of

a magnetic needle. The cut shows, in section, the cable of the Submarine Telegraph. The black dots in the centre of each strand are the cut ends of the wires.

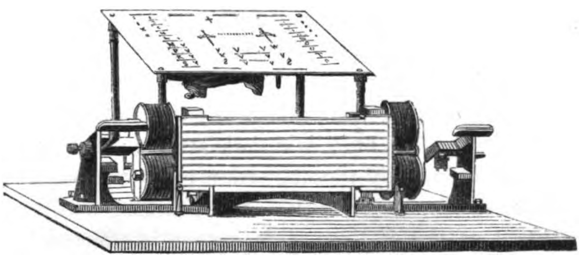


The production and transmission of the force having now been considered, we may briefly notice the construction of the Needle Telegraph. The cut represents one form of Needle Telegraph, in which a number of keys are connected with the needle apparatus. A small case, somewhat similar to that of a time-piece, and having a dial at the upper part, and two handles at the lower, is



placed in one part of the Telegraph Office. Connected with it is a wire which mounts up to the roof, and passing out proceeds to join the string of wires suspended on posts. Through that wire comes an invisible mes-

sage, sent from a person a hundred miles away. Entering into the body of the apparatus it passes through a coil of wire, and instantly it will be observed that the needles on the dial-face are in motion. There are generally two needles, and as the current flies through the wire it deflects these to the right or to the left at the will of the message-sender. The reply is now to be made, and the clerk takes both handles, and begins moving one to one side and the other to the opposite, and reads in the face of his own instrument the commotions which he is now producing in the distant one, for they are connected and simultaneous. From what has already been stated, it will be understood that whatever mechanism may be employed in effecting this, and it is very



simple, it is merely by virtue of the deflecting power ot the galvanic current that the needle moves. The handles transmit the current from the battery through the instrument to that at a distance, and the code of signals is made up of a certain number of movements of the needles either to the right or left, and of their combinations. In order to call the attention of the clerk, the current passes through an apparatus which moves a bell, and when a message is about to be sent the bell first rings to warn the attendant of the fact. Mr. Henley's telegraph is shown in the cut. It differs from that of Messrs. Cooke & Wheatstone in some respects, and the

needles are deflected by magneto-electric action, instead of by the battery.

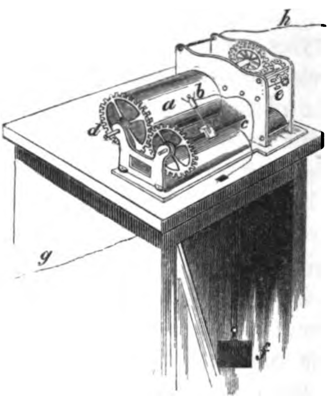
The Printing Electric Telegraph may be arranged under two divisions; the first, comprising those which print the message by chemical agency; and the second, those which do so by mechanical arrangements. Mr. Bain's and Mr. Bakewell's telegraphs are those which act on this principle. It is well known that if an electric current be passed through paper moistened with certain chemical substances, a decomposition of those substances will ensue. If, therefore, a series of intervals were made in transmitting the current through the wire, and the paper were drawn along continuously, it is obvious that marks could be produced which might serve as signals. Mr. Bain's telegraph depends on the development at a distance of the chemical effects of electricity. The effect produced is the precipitation of Prussian blue on paper, duly prepared by impregnation with prussiate of potash and weak acid, on the contact of a steel pointer, at the signal station; this contact being determined by the attraction of an electro-magnet on the arm which carries it. The breaking and renewal of contact at the station of departure is effected by the interposition of a band of paper, drawn uniformly along by clock-work, and punched out in holes and slits of different lengths, which allow of more or less prolonged contacts, in conformity with a conventional alphabet. At the station of reception, a large circular disc of the prepared paper is made to revolve uniformly, by simultaneous clock-work, while the iron point, which on every renewal is pressed into contact with the paper, is carried to or from the centre current uniformly by a screw motion, along a line to the centre of the disc, and leaves traces on the paper as it passes beneath it, in Prussian blue corresponding to the stamped line in the original paper band, and which may therefore be read off at

leisure; other preparations, such as that of starch with iodine, potash, &c., may be used for preparing the paper. There is much mechanical ingenuity and skill displayed in every part of this apparatus.

Mr. Bakewell's is a still more singular instrument, as may be imagined from the fact, that it actually copies the writing of the person who transmits the message. Hence it is appropriately designated the Copying Telegraph. The manner in which this most wonderful result is accomplished is as simple as it is beautiful. The transmitting and the receiving instruments are counterparts of each other. Trains of wheels impelled by weights are employed to impart equal movements to cylinders in each instrument. Screws placed parallel to the cylinders, and rotating with them, serve to carry metal styles, which press lightly on the cylinders, from end to end. The metal styles are insulated by being attached to ivory arms connected with brass nuts that traverse on the screws. One of the poles of the voltaic battery is connected with the cylinder of each instrument; the other pole of the battery is connected with the metal styles, so that the electric current may pass from the styles to the cylinders. The message to be transmitted is written on tin-foil with a pen dipped in sealing-wax varnish, and it is placed on the transmitting cylinder. When the instrument is set in motion, the metal style presses on the writing as the cylinder revolves; by which means the electric circuit is broken every time that the varnish interposes. Upon the cylinder of the receiving instrument, paper, moistened with an acidulated solution of prussiate of potass, is placed, and the metal style employed being a piece of steel wire, the electro-chemical decomposition that occurs whenever the electric current passes, produces a line of Prussian blue on the paper. If there were no varnish-writing to interrupt the electric current, the revolution

of the cylinder, and the gradual advance of the marking point by the screw, would draw a number of continuous blue lines spirally on the paper, but so close together as to appear parallel. The interruptions, however, caused by the interposition of the varnish-writing on the transmitting cylinder, break the electric circuit in those points, and cause a cessation of marking whilst the style is passing over each letter. As the style traverses several times over each line of writing, the successions of interruptions, by corresponding with the forms of the letters, produce an exact copy of whatever is written or drawn on the tin-foil message; the writing appearing of a pale colour on a ground of closely-drawn blue lines.*

The cut shows this ingenious instrument. *a*, the cylinder of one of the instruments; *b*, the metal style,



connected by the wire, *g*, with one pole of the voltaic battery; *o*, the ivory arm to which the metal style is attached, and which insulates the style from the screw; *c*, the screw on which the style traverses as the cylinder revolves; *d*, cog-wheels to turn the screw; *e*, a fan to regulate the speed of the instrument; *f*, the impelling weight; *h*, the wire connected with the distant instrument.

There is probably no single instrument connected with this most interesting subject which more remarkably evinces the power acquired by man even over events at a distance than this. By its means the autograph of a person, or even his likeness, might be most

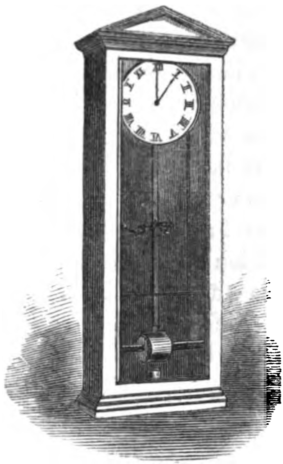
* Official Catalogue, Great Exhibition, 1851.

faithfully transmitted through the electric wire to a distance of hundreds of miles in a few seconds.

The Electric Clock must next come under notice. The transept of the Great Exhibition building was supplied with one of these, and the hands were outside, the figures being arranged in a semicircle, and placed at the intersections of the radial bars with the second semi-ring from the centre of the great fan-light. The principle of this clock was the following:—the power of an electro-magnet is employed to bend a spring to a certain fixed extent, the reaction of which on being released gives the necessary impulse to the pendulum. The pendulum is thus driven from side to side by the elasticity of the spring, but the force used to draw back the spring is that of electro-magnetism. The electro-magnets were kept in action by a series of small batteries, and by connecting wires with the pendulum. Two other clocks at each extremity of the building were kept at the same rate with that in the transept. This invention did not answer very well in the Exhibition, probably in consequence of the great agitation in the galleries. But it is used at the Station of the Great Western Railway, and in one of the large wholesale city houses, and all the clocks in the establishment are kept together by the single pendulum, which is placed in the counting-house. The wire used for them is about a quarter-of-a-mile in length. It will of course be understood that there are no weights in these clocks, and that all which they need to keep them constantly going is occasional renovation of the battery. The hands of the Exhibition clock were of the respective length of 12 feet for the hour hand, and 16 for the minute hand. Nearly 25,000 feet of wire were used for it, and eight pairs of Smee's batteries. These only required looking after once in the space of two months.

Mr. Bain's electric clock has been well known for

some time, and there existed recently a shop in Bond-street where these clocks were made for public sale.



The cut represents the ordinary form of this clock. It is not difficult to understand the principle of this clock. We have already explained that by making or breaking the contact of a wire through which a galvanic current passes, we can call into action or annihilate the powers of an electro-magnet. Thus it may be made at one moment to attract with great power, and at the next to be powerless. Let us observe this principle in its present application. In Mr. Bain's clock there are two very fine copper wires fixed in the angles of the clock-case, which communicate with similar wires at the back of the pendulum bar, and are thence continued to a coil of the same kind of wire, surrounding an armature of soft iron, and the whole of which is inclosed in a circular brass box. This box constitutes what is usually termed the bob of the pendulum; but while it answers that purpose, it performs another and most important duty as an electro-magnet. The box is hollow in the direction of its axis, and the cavity thus formed admits of the insertion of two sets of permanent magnets, whose similar poles are placed near to, but not in contact with each other. These magnets are kept in their place by being inclosed in brass boxes secured to the sides of the clock-case. In connecting the wires with a battery of coke and zinc buried in the earth the pendulum is set in motion, and by an ingenious piece of mechanism the current is alternately broken and renewed, and the pen-

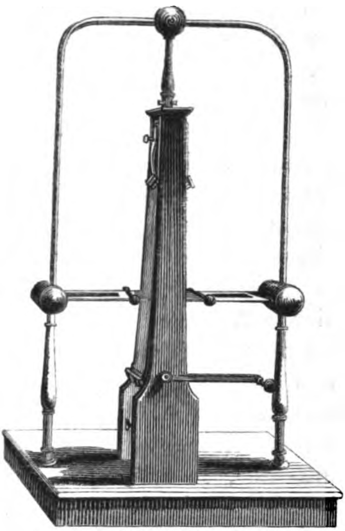
dulum is drawn from side to side. By means of a wire connected with this clock any number of others can be kept in motion, and all will record the same time. These clocks have been very extensively used, and are said to be good time-keepers.

In order to develop active electricity, a variety of machines have been used. The ordinary plate-glass electrical machine is well known. Mr. Armstrong's most singular machine for generating it by the friction of high-pressure steam against the mouth-pieces of a number of steam-pipes, has also been publicly exhibited for some years, and created much interest at the period of its first introduction. A large specimen of the hydro-electric machine exists at the Polytechnic Institution, and a model was also sent to the Great Exhibition. One of the most interesting and powerful of these machines is of still more recent introduction—the gutta percha electric machine, invented by Mr. Westmoreland, exhibited in 1851, and represented in the annexed cut. This machine consisted of two rollers of equal diameters placed one above the other, over which a band of gutta percha, four inches in width, is stretched. Opposite to the axis of each roller, and on either side, are placed two brushes of bristles. There is a double conductor connected by a curved brass rod hanging over the top of the machine, similar in form to the conductor of plate-glass machines, and also a simple means of tightening or loosening the band, to correct the expansion and contraction of the gutta percha.

It is stated that the electricity given off is of high intensity, and, under favourable states of the weather, nearly as much in quantity as that from an ordinary plate-glass machine of large size. The machine exhibited, when in good order, gave off sparks from about three-quarters of an inch to an inch in length.

This application of gutta percha is quite new in prac-

tice, and indicates the discovery of a new source, which promises to be a means of obtaining a supply of



electricity of almost unlimited extension; this application of gutta percha opens a new field in electrical research well worth exploring. A Prize Medal was awarded to this machine. It has also been found that vulcanized caoutchouc is even a more powerful source of electricity than gutta percha.

Before passing from the allied sciences of Electricity and Galvanism, we must briefly advert to the interesting subject of the Electrotype. It may more appropriately be termed a process than an instrument of philosophy. When a galvanic current is passed through a solution of a metallic salt it decomposes it, separating the metal from the other chemical elements, and precipitating it in a fine layer which solidifies into a sheet. The applications of this simple but important principle are infinitely varied, and have reached a very high state of perfection in our own time. If any object, to which a conducting surface is given by means of plumbago, or otherwise, be placed in a solution of gold or silver, through which the galvanic current passes, it will very quickly become coated with a most pure and beautiful deposit of the precious metal. To such a degree of delicacy does this take place that the most minute detail is accurately copied. Thus even the surface of a daguerreotype plate, with all its fine and delicate repre-

sentations, may be accurately copied by the electrotype process. The Great Exhibition contained many most remarkable triumphs of this art. There were some humming birds, having every feather and all their most minute markings shown upon them; also some butterflies and other insects, with every hair and the down copied, and even the more minute microscopic markings. Until recently it was thought that only the pure metals could be deposited, but Capt. Ibbetson has perfected a process by which he throws down tin, bronze, and also alloys of copper and gold, &c. The general aspect of the newly precipitated metal is whitish and dull, but it has been found that the addition of a little sulphuret of carbon to the solution causes the deposit to be as bright as if it were polished by hand. Electro-metallurgy has been carried on to a very large extent on the Continent, and in Russia the vast cathedral of St. Isaac at St. Petersburg is ornamented with sculptures entirely formed in this way. All the gilding of the dome and other parts has been accomplished in the same way. At the Great Exhibition the Austrian government exhibited some remarkable specimens of this kind, among which was an immense sheet of copper, entirely deposited from a solution of the metal. At the Great Exhibition were some glass vessels which excited great interest, from the curious manner in which they were covered with copper.

Vessels thus covered with copper were first exhibited at the French Exposition in 1844. These vessels excited great curiosity, and occasioned much perplexing speculation as to the mode of their production. The coating of metal was applied in so smooth, perfect, and uniform a manner, as to render it evident that none of the ordinary methods of metallurgy had been adopted in their manufacture. These vessels were coated by electrotype process, and similar apparatus is now made

for chemical purposes in England. The surface of the glass or porcelain is first varnished, then brushed over with bronze-powder, in order to form a conducting surface on which to deposit the copper, and the vessel is then placed in the decomposition-cell, in connexion with a battery. In a few days the whole external surface is covered with bright metallic copper.

The philosophical instruments connected with the subject of Heat, are few in number and very simple in construction. These depend entirely on the mechanical effects of heat, and measure its intensity entirely by its results in the expansion of bodies. The thermometer measures the intensity of heat in the substances to which it is applied, by the expansion of a column of mercury, hermetically closed in a glass cylinder. The ordinary forms of this instrument are well understood. There are, however, certain thermometers which are self-registering, a notice of which may be interesting. One of the best and most recent of these is the thermometer invented by Messrs. Negretti and Zambra. In this instrument, a small piece of glass is inserted near the bulb and within the tube, which it nearly fills. On an increase of temperature, the mercury passes this piece of glass, but on a decrease of heat, not being able to repass, it remains in the tube, and thus indicates the maximum or greatest temperature. After recording the degree, the mercury is easily made to go back again. These instruments are now used in the Greenwich Observatory. Other self-registering thermometers are made with a small piece of steel, which is pushed forward by the mercury, and remains at the highest temperature to which the mercury rises. The instrument for registering the lowest temperature is a thermometer in which spirits of wine is used, and a small index floats in it, which is drawn after the column as it falls, and remains at the lowest point to which it is thus drawn.

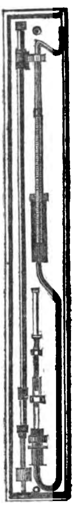
By this apparatus, an observer who may leave his instruments for twelve hours, will readily be able to determine the highest and the lowest ranges taken by the thermometer during his absence.

In Mr. Brooke's ingenious contrivances before noticed, the registration of the highest and lowest and all intermediate degrees of temperature, is effected by photography.

The inventor of the caloric-engine, Mr. Ericsson, of America, exhibited in 1851 a pyrometer, for measuring temperatures from the freezing point of water to the melting point of iron. This instrument consists of a tube of platina containing air or gas, to which the heat is applied. This tube is connected with an ingenious arrangement, by which the air or gas which it contains can be measured off. By this means, very high degrees of temperature can be registered without injury to the instrument. Other pyrometers are made, which measure off great intensities of heat by the expansion of metal rods, or the contraction of earthenware balls, the amount of which is then measured off on an index.

Intimately associated with the thermometer, in meteorological science, is the barometer. Great improvements have been made in this instrument of late. The standard barometer, designed by Dr. Prout, and exhibited by Mr. Newman, is a good specimen of one of the best instruments of this kind. In this instrument, the scale is raised or lowered by a rack and pinion, and is connected with a rod that passes through the top of the istern, and is brought into contact with the surface f the mercury in the cistern previous to observing the height of the column. This instrument is very carefully constructed. The tube is filled with mercury, and boiled under a diminished atmospheric pressure: for it has been found that mercury highly heated in glass tubes becomes oxidized, and that all tubes boiled under

atmospheric pressure are foul. At the Great Exhibition, Messrs. Negretti and Zambra showed a self-registering maximum and minimum barometer, which was quite a novel arrangement, and whatever its merits as an instrument may be, it was interesting as a curious specimen of workmanship in glass-blowing. A second and smaller piece of glass tube is placed parallel to the upper part of the tube, and joined into it above and below by transverse portions; there is also another piece of small tube placed parallel to the short arm of the syphon, and likewise joined into it, near the bend: in these last tubes the mercury falls, as it rises in the former, simultaneously. In each of the secondary tubes is a small float similar to a Six's thermometer; the upper tube will consequently indicate the maximum, and the lower the minimum point. Another very good barometer was shown by Mr. Davis: it consisted of an ordinary barometer tube, with an ingeniously constructed air-



trap at the top of the tube, consisting of a piece of smaller tube united to the former, and bent down, and then up again, like the letter "S." Any small bubble of air may be thrown up to the sealed end of the tube, and trapped by a little mercury in the lower bend. By these means a perfect vacuum may be insured. This barometer is shown in the cut.

One of the most novel forms of barometer is what is called the aneroid, of which many examples are now to be found on drawing-room tables. This instrument is constructed on the following principles:—Its action depends upon the varying effects of atmospheric pressure produced upon a metallic box exhausted, or nearly exhausted, of air. The small vertical motions resulting from an increase or diminution of atmospheric pressure upon the surface of the box, are converted into

large horizontal movements by a system of lever and spiral springs. With these the index is connected, and the usual marks, Fair, Rain, &c. are engraved on the dial over which it moves. One of the greatest objections to the ordinary barometer—the glass tube, and the fluidity of the mercurial column—is thus obviated; and a most compact and ornamental instrument, quite accurate enough for domestic use, is produced.

An instrument still more interesting and ingenious is that recently invented by M. Bourdon, a French engineer, to which a council medal was awarded, and which has attracted much attention in this country and in France. From M. Bourdon's own account, we extract the following brief notice of the principle he has so ingeniously applied. The law upon which his instruments depend may be thus explained:—

If a brass or thin sheet iron or steel tube be nearly flattened, and afterwards coiled, the effect of an internal pressure of steam or water is to force it towards its original shape—the first effect produced being that of tension towards elongation, whether the flattened tube be coiled or twisted; and a contrary effect is produced by unresisted exterior pressure. In giving the tube its curved form it retains a considerable degree of elasticity, and will act as a good spring, and work from or back to its newly-acquired shape, as the pressure upon it may be varied. A simple piece of well-made metal tube is first partially flattened in all its length, and bent into a semicircle. One end of it is hermetically closed, while the other end is left open, to receive the pressure of steam or water. To the end that is sealed up a hand is fixed, which is so arranged as to show the variations in the position of the tube upon a dial marking the degrees of pressure. A most excellent pressure gauge of great simplicity is thus constructed. A vacuum gauge is made in the same way by reversing the application of pressure, and, conse-

quently, the effect upon the tube. As exhaustion takes place in the tube, so does its power of resisting the pressure of the surrounding atmosphere which acts upon it vary, and it consequently bends under that pressure in regular ratio with the variation of it, and is thus made to indicate the degree of vacuum in the condensers of an engine. A barometer is made in the same simple manner, by completely exhausting the air from the coiled tube, and hermetically closing it. As the pressure of the atmosphere varies, so does the tube vary in its curvature; and thus, with the greatest accuracy, such an instrument indicates the smallest variations of atmospheric pressure, and forms one which, from its solidity and simplicity, appears to be preferable to any other barometer.

To form a thermometer, the same principle is applied. For indicating the temperature of liquids, the tube is generally twisted in its whole length, instead of being curved, and being filled with alcohol it is well closed; and thus, as the temperature varies, so will the alcohol in the tube expand or contract, and force the tube out of its natural shape, and thus indicate the variations of temperature, either of the surrounding atmosphere, or of any body or fluid into which it may be plunged. Several other applications of this discovery in physical science have been made by the inventor—such as a steam-engine indicator, a gas regulator, and even a model of a steam-engine, &c.

The principle thus cleverly applied is certainly one of extreme value, and it remains to be seen in what new directions it will be adopted. It is used in many of the locomotives as a pressure gauge in France, and has also been adopted by some of our best engineers in this country.

Before passing from meteorological instruments, there remains a curious combination of apparatus for regis-

tering atmospheric phenomena, which deserves notice. This is Dollond's Atmospheric Recorder. The paper upon which the registration is effected in this instrument is rolled on a cylinder driven by clock-work, and in contact with pencils connected with the different apparatus employed. The barometer records the rise and fall of the mercury by a float attached to the pencil, through a lever arrangement. The thermometers effect the same object by being placed in a balance, the variations in their

column affecting the rise and fall of the balance. The hygrometer is made of a piece of mahogany cut across the grain, the variation in the length of which under the influence of atmospheric moisture, are also registered by a pencil. The pluviometer catches the rain, and by a float records its amount. The electrometer, by an ingenious arrangement, registers electrical phenomena, by a movable disc. Lastly, there is an anemometer for recording the pace and also the direction or the wind. Thus a very complete series of instruments is collected

together into a sort of miniature observatory, the external appearance of which is shown in the cut. For ordinary observations, these arrangements are probably sufficiently accurate, but for careful scientific research they will scarcely be thought so.

Among other instruments for measuring physical effects, one of the most important is the Balance. Of this many excellent specimens were first seen by the general public at the Great Exhibition. Ordinarily these instruments are confined to the laboratory. The balances of Mr. Oertling were constructed with great care. The largest of these would weigh up to 56 ℔s., and would even at that weight turn with a quarter of a grain. The beam was a single casting, in which lightness and strength were admirably combined. The form of it is a pierced rhomb, strengthened by thin but very prominent ribs. We may here remark that the most important characteristics of a well-constructed balance-beam are lightness and stiffness combined. Any unnecessary weight in the beam, by increasing its inertia, renders its movements more sluggish under the influence of very small differences of weight, and thus diminishes its sensibility; at the same time a sufficient amount of stiffness is required to ensure the absence of either temporary or permanent flexure from the action of the largest weights it is designed to carry. Another of this maker's balances was calculated to carry 1℔. in each scale, and a third, which is of white metal, 1,000 grains. The beams of both are pierced rhombs, and the scales, as well as the beams, are supported by agate knife edges, resting on agate planes. This arrangement of the knife-edges has been found to wear very well, and must be advantageous in the laboratory, as the steel knife edges are liable to be impaired by rust.

The most ingenious machine of Mr. Cotton, employed at the Bank of England in weighing coins, is a very beautiful application of the balance. This machine

separates those coins that have, from those that have not, a certain assigned weight. A pile of coins being placed in a tube, the lowest is pushed out by a lever and deposited on the end of the beam, which, if the coin is of full weight, is depressed through a small space, but if it be too light, the beam remains stationary. A small piece of steel now advances from one side, on a level with the position that a heavy coin assumes, and immediately afterwards another advances from the opposite side, on a level with the position of the light coin. If the coin has full weight, the first advancing piece pushes it into a receptacle, and the second has no effect; if, on the contrary, the coin is light, the first passes under it, and the second strikes it into another receptacle. In actual use, these operations are performed with great rapidity.

Clocks, surgical instruments, and musical instruments have been reckoned among the instruments of philosophy. But it is not our intention further to pursue this subject. From the notices of the most important philosophical apparatus we have given, a good idea may be gained of the value of such instruments in the pursuit of experimental knowledge. Yet the various organs of man himself present us with specimens of instruments far more ingenious and perfect in operation than any used by philosophers. What photographic camera and lens can compare with the human eye? what instrument for measuring vibrations with the ear? what musical instrument with the voice? or what machine of manifold application with that masterpiece of mechanism—the human hand? Experimental philosophy is truly a noble department of knowledge, and its instruments are wonderful in their nature and operation. But the Divine Hand has produced far nobler works than these, and the most refined physical science is but a little beginning in the knowledge, and a faint imitation, of the works of God.

CHAPTER VIII.

GLASS AND PORCELAIN.

To how great an extent the arts of the glass-maker and the potter have contributed to the advancement of industrial resources, and to the development even of scientific knowledge, may be best conceived when we reflect upon the infinite variety of purposes to which these substances are applicable. What were chemistry, astronomy, meteorology, and physical science generally, without the retort, the lens, the thermometer,—without glass, in short? Nor is porcelain less important in its place. The most important vessels of the laboratory are of this substance, while in domestic applications it is employed for all the multifarious uses of the table. Glass and Porcelain, although not coeval in their history, nor identical in their composition, nor yet applicable to the same uses, may be conveniently studied under one head, and we purpose to offer a sketch of the manufacture and recent improvements in both these important materials. In so doing we shall confine our attention exclusively to a sketch of these arts as they exist at the present hour, for the historical details of their manufacture have long been familiarly known to almost every reader.

Glass being composed of silica in combination with

potash, soda, lime or lead, is made out of a skilful combination of these materials, or of some part of them, under the influence of intense heat. There are, however, several varieties of glass, each differing from the rest in its composition, and also in its physical properties. The first of these is flint-glass or crystal, which is a compound of silicate of potash and oxide of lead. The next is plate, crown, and sheet-glass—all nearly identical in composition, but differing in their mode of manufacture. These varieties consist of silicate of potash, soda, and lime. Lastly, there is the common green-glass,—which is a compound of silicate of soda, alumina, and iron. Into the manufacture of crown, sheet, and flint-glass, in addition to the materials already named, manganese, charcoal or anthracite, and arsenic enter. The action of the arsenic is not clearly understood; it appears, however, to ensure brilliancy, although the whole of this metallic oxide escapes in the process of melting. The sands employed for these glasses usually contain some traces of iron, and a very small quantity of this metal imparts colour to the glass, owing to the peroxidation of it by the heat. Hence charcoal and manganese are introduced, to prevent this and to secure whiteness. The peculiar white character of the German sheet-glass is due to this action of the manganese. It may act both chemically and physically—chemically by preventing the further oxidation of the iron, and physically by producing a pink tint which is the complementary colour to the green given by iron—thus producing a neutral or white glass.

The usual formula for forming the *batch*, as the glass mixture is termed, is—one part (by weight) of alkali, two of lead, and three of sand. The materials, having been carefully weighed, are intimately mixed, and upon this depends the homogeneous character of the melted mass. If this is not secured, the glass is full of striæ,

arising from the unequal specific gravities of the various materials, and the consequent currents set up in the mixture by the endeavour of each to obey the law of gravity. Professor Faraday proved the following differences of specific gravity to exist between glass taken from the top and from the bottom of the same pots:—

Top	3·38	3·73	3·85	3·81
Bottom . . .	4·04	4·63	4·74	4·75

It is this difficulty which prevents the manufacture of large achromatic lenses. Many attempts have been made to overcome the defects of the striæ, but they have hitherto been only partially successful.

All the arrangements of the pots and furnaces are attended with difficulties peculiar to themselves; but passing these by, we may consider that we have obtained a homogeneous and transparent material, which we are now to trace assuming that form, in which it becomes available for the varied uses to which it is applied. We shall select the apparently simplest form first—the production of a lens. The process is as follows. A sugar-loaf-shaped ladle, about five inches in diameter and seven inches deep, is carefully dipped into the molten glass, and when filled is taken out to cool a little. A blowing tube is then attached to the large end, and the mass is held before the mouth of the furnace to be reheated. When it is sufficiently softened it is blown out into a cylinder, the ends are then cut off and the cylinder is flattened into pieces or plates of fourteen inches long, ten wide and about half-an-inch thick. These plates are then annealed and sold to the optician for cutting and grinding into discs. The great difficulty, however, is to produce a piece of glass without the streaks or striæ, to which allusion has been already made. M. Guinard, a French glass-maker, in order to avoid this defect, agitated the glass while melted, then cooled down the entire contents of the pot, and annealed the whole. When

cool he then cut out the best portions, and afterwards softened them in clay moulds. In this way beautiful optical glass was produced. The French makers are certainly in advance of ourselves in the production of those finer qualities of glass, and until recently, almost all which was used by opticians was obtained from abroad. At present, however, British manufacturers are producing excellent glass, and the real reason of their inferiority is a commercial one,—for it is found that it is not worth the manufacturer's while to take pains to make this sort of glass, since the commonest kinds are much more remunerative. Such being the case, one of the great stimuli to improvement is wanting and the foreign makers will probably still retain their preeminence in this art.

One of the most interesting and wonderful specimens of what a British manufacturer can produce when he makes the effort, was sent to the Great Exhibition of 1851, by Messrs. Chance, of Birmingham. This was the immense flint-glass disc, which excited so much interest at the time. Its dimensions were as follows:—Its largest diameter was 29½ inches, and its thickness from 2.2 to 2.25 inches. Its weight was about 200 ℔s. and its specific gravity about 3.56. The surfaces were highly polished, and it underwent a severe examination from the members of the Jury. Polarised light was passed through it, and it was tested for a time by covering it in a dark room with a glare of light from another lens, and was found to be a remarkably fine specimen of glass. With the exception of a little cluster of striæ in one part, it was of first-rate quality, and since these could be cut out in grinding it into a lenticular form, it was obvious that they were not of much consequence. By treating the lens differently, however, it was shown that a disc of at least 25 inches, that is—upwards of two feet in diameter—could be produced of glass—considered as

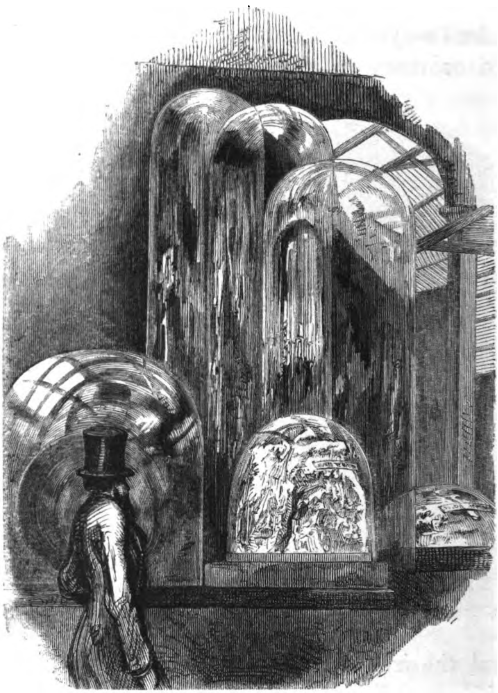
absolutely perfect. The largest lens yet made has not exceeded 16 inches in diameter; the present glass was therefore a great stride in advance of its predecessors, and appeared to promise wonderful results for the purposes of high astronomy when actually formed into a telescope. As yet, however, this has not been accomplished. Some splendid lenses were also exhibited of flint-glass, by M. Daguet, a Swiss manufacturer. One of these was upwards of 15 inches in diameter. This flint-glass was extraordinarily dense and hard. Its specific gravity being nearly 4°, and it is extensively used by all the best opticians in this country. For this glass of M. Daguet, and also for the magnificent disc of Messrs. Chance, the Council Medal was very properly awarded.

The manufacture of window-glass is carried on in two ways. First, by what is called the cylindrical process, which produces sheet-glass; and secondly, by the effect of centrifugal force, the product of which is called crown-glass.

In the first, as soon as the fused metal is in a condition for working, a sufficient quantity is collected at the extremity of a pipe, and then lengthened by swinging, and blown at the same time, till it acquires the form of a hollow globe, or cylinder, open at one end, and adhering to the mouth of the tube at the other. The cylinder is then detached from the tube, the neck being cut off with a thread of hot glass, and one side of the cylinder is opened with a heated iron or diamond; after which, it is taken to the flattening kiln, in which it is heated to softness, and rubbed down, either upon a stone or upon a sheet of glass, called a largre, by means of a block of wood, called a polissoir. The sheet, thus obtained, is then placed in an annealing kiln, and left there to cool gradually.

By the second operation, the glass collected at the

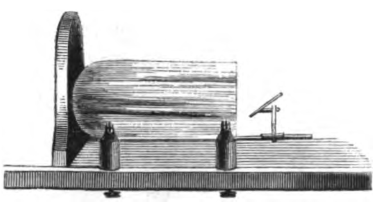
furnace upon the point of the blower, and is then blown into a spherical form. It is then reheated in the furnace, and swung in the manner shown in the cut, above the head and below the feet of the workman, until it assumes the form of a cylinder. In performing this operation the workman stands upon a stage opposite the

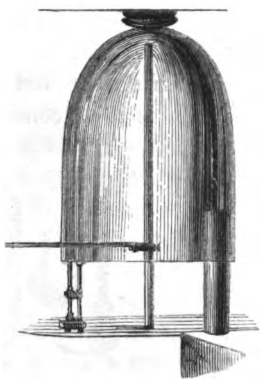


mouth of the furnace, with a pit or well beneath his feet, six or seven feet in depth. He swings and balances the molten metal until it is expanded to the proper length. The least miscalculation of his power of swinging it, or a very small deviation from the proper curve, might dash the red-hot glass either against the side of the pit, or against the walls of the building. But long use and

great dexterity render such an accident seldom if ever possible.

The first stage in the production of sheet glass is now completed, and a large cylinder is produced; and if it were to stop here, it would form a splendid glass shade; such, in fact, is the mode in which they are made, and the cut will convey an idea of the dimensions of some sent by Messrs. Chance to the Exhibition. These are supposed to have been the largest ever made, and this may well be understood when it is stated that one of

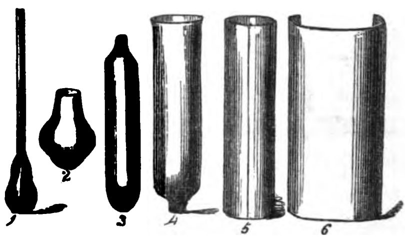




them was sufficiently capacious to cover over a man of about five feet in height, in a standing posture. The further progress of sheet glass is as follows. Boys with strings of red-hot glass separate the cylinder from the blowing iron, and also cut off its closed end. They then take the tubes thus formed under their arms, and remove them to another part of the building, where they stand on end, prior to being annealed, like so many chimney pots. The tube is then cut down the middle, and being placed in a heated room, called the flattening kiln, it soon opens out, and being pressed down by the workman, it quickly becomes flattened out on a slab of stone. It is then quickly smoothed with a wooden

implement, and passed to the cool end of the kiln by degrees. It is then tilted on its edge, and the manufacture is complete. The cut below shows the gradual progress of the manufacture, from first to last. If the manufacturer merely wishes to produce a glass shade, the cylinder is preserved, being detached from the blowing tube. But in order to cut it evenly, and of the requisite size, an ingenious machine is employed, which is shown in the cut on the last page, and was invented by M. Claudet. It consists merely of a frame, in which the cylinder is supported vertically or horizontally, while the diamond set in a little frame is made to act against the surface so as to cut it.

In the year 1840, a new variety of window-glass, which is now coming still more extensively into use,



and is as far superior to sheet glass as that to crown, was introduced by Messrs. Chance. This is called Patent Plate, and forms a very large part of what are called the plate-glass windows of modern times in the metropolis and other large towns. This beautiful glass is made in the same way as sheet-glass, but of greater thickness, and great care is taken to flatten it out thoroughly. It is then ground and polished in the same way as ordinary plate-glass. The surface of this, though not quite, is very nearly true, and its transparency and brilliancy are quite equal to cast plate.

Plate-glass, such as is used for mirrors, belongs to another kind of glass, and is to be arranged under the

head of cast glass. It is in reality cast in an iron mould, and afterwards polished. A quantity of melted glass is poured from the pot upon a cast-iron table, and is then rolled out by an iron roller. In this way a large slab of glass is made, and its surface after annealing is ground down and finely polished, by friction with another slab of glass. An immense amount of plate-glass is now produced annually, amounting, as it is stated, to upwards of ten millions of square feet. It is used in the rough state also, as a covering to railway stations, and similar places, and is well adapted for such a purpose. A new kind of plate-glass, with a number of longitudinal perforations in it, has of late been introduced, for the purposes of ventilation. This glass appears to be formed by being cast in a mould, and then perforated by a plate of iron, studded with thin projecting pieces, so that the plate is perforated wherever these pieces have been placed. Mechanical means are also used to give a ribbed surface to plate-glass, in order to make it more dispersive of light; and this sort of glass is much employed as a substitute for ground glass. Messrs. Powell & Sons have also a sort of moulded glass, which they use for windows. The pattern is pressed in the glass by a mould, and then, by a subsequent process, glass of another colour is allowed to flow into it. The whole is then ground down to a uniform surface, and the result is, an inlaid pattern of glass of one colour, in glass of another. The windows thus formed are pleasing in their appearance, but want brilliancy of colour. Among the triumphs of the plate glass-maker must be reckoned those vast specimens of glass exhibited by the Thames Plate Glass Company in 1851, and illustrated in the first part of this work. One of these glasses was the largest in the world.

Flint-glass, or crystal, forms one of the most beautiful

varieties of this beautiful material, and in its manufacture into the various objects employed both for ornament and use, many highly interesting and ingenious methods are adopted, some of which we shall now notice. Moulded flint-glass may be considered one of the most important modern improvements. Almost every reader is familiar with this form of the material, for moulded articles for almost every variety of table use are so abundantly made now as to be found even on the tables of very humble persons. Its refractive and cut-like effects are so similar to those obtained at a much greater cost by cutting the glass, that it is not always easy to determine whether it is really cut or not. The peculiarity of modern moulded glass is, that the interior of the article has no indentations corresponding to the figure outside, and its lustre is consequently due to the inequalities of its substance.

It is manufactured in the following manner. The metal is first gathered on a rod in the ordinary way, and allowed to cool a little. Some more is then taken up, and the mass is immediately pressed into a metal mould, on the interior of which the figure to be impressed on the glass is indented. In this way, the exterior coating only fills the indentations, the cavity in the interior preserving its smooth and circular form. When about half formed, the projecting parts are made slightly to separate from each other, by quickly turning the rod, while the workman at the same time blows into it. The article is then brought as usual into the desired shape, and in order to give it a polish, it is exposed to heat just sufficiently slightly to melt its external surface, which is called the fire-polish, and is then annealed.

What is called Pressed Glass is a variety of the last kind. The operation of its production is extremely simple. A die and mould of the required shape are secured on a table. The die is capable of being

plunged into the mould by a lever, thus forcing down the glass before it, and causing it to assume the shape of the mould. It requires much practice to collect the exact quantity of fused glass necessary, and if this be not the case, the article is spoiled. It is an extremely rapid and cheap mode of producing glass objects. The effect is not so good as the last, and this method is chiefly confined to the production of very common articles.

Another variety of the pressed glass manufacture is what is called Drop Pinching. It is employed chiefly for making the drop-work and spangles of chandeliers, &c. Lumps of glass are made expressly for this process, and are softened in a blast furnace. When sufficiently soft, they are then squeezed in pairs of hot brass dies, and the required form is thus given to them. In order, however, to fit them for use, they require to be cut and polished in the same way as ordinary cut-glass.

A very interesting kind of glass, resembling the pillar moulded in some respects, is the modern revival, by Mr. Pellatt, of what is well known to connoisseurs as the Venetian Diamond moulded. The old Venetian diamond glass was formed by impressing glass in a metal mould fluted within, and then, while the glass was soft, pinching up the flutings and diamond-shaped divisions by the common glass-worker's tool, called the pucellas. Every diamond was thus pinched up one by one, and the production of a single specimen of these beautiful goblets was therefore a work of great time and much skill. Very recently this has been re-introduced, but a very different mode is adopted in order to make the diamonds. A mould of brass is cut, so as to have the diamond figure within, and the soft glass, on being blown into this mould, at a single operation obtains the required ornament.

We have now to notice some very curious portions of

the glass manufacture, which would seem to belong rather to the regions of taste and art than of manufacture. For our information on this and allied subjects, we must express our acknowledgments to Mr. Pellatt, who has exhibited to us his most interesting collection of ancient glass, and his still more interesting and successful attempts to reproduce many of what were thought to be lost arts in this department of industry.

The first of these which we shall notice is the Venetian Filigree glass. The basis of almost all the ornamental art of the Venetian glass-worker consisted in the production of solid canes of glass, composed of a variety of threads of different colours. These canes are often seen as ornaments in our drawing-rooms, and their manufacture is thus carried on. Pieces of plain, coloured, or opaque white solid rod, called "cane," are first prepared by simply drawing out into a long rod, or thick cylinder of glass of the required colour. Now, in order to combine these together into one, so as to produce a stick of various colours, the process is as follows:— A number of these rods are cut into lengths, and are then put into a cylindrical mould, with suitable internal recesses, and both the canes and mould are moderately heated. The blower then prepares a solid ball of transparent flint-glass, which being pressed in contact with the various canes at a welding heat, causes them to adhere. The solid ball is then released from the mould, and is reheated and rolled, till the canes are thoroughly incorporated into it. The mass thus produced is next covered with a gathering of white glass, and by simply drawing this out, a compound rod is produced of many colours. A spiral direction can be given to the lines of colour by simply twisting round the ball, before drawing it out. In this ingenious way the most apparently elaborate and complex ornament is produced. Yet it is

all a homogeneous mass, and the joints of the different pieces of which it was originally composed cannot be detected.

Still more perplexing to an uninitiated person is the Venetian Ball, at present one of the most popular ornaments of the drawing-room, but until recently confined, owing to its great price, to the wealthy. What is called Mille-fiori is the same kind of work, but is wrought into other forms, such as tazzas, paper-weights, &c. The method adopted in the manufacture of these objects, is to form a sort of pocket of clear flint-glass; into this a number of small pieces of filigree cane and glass are dropped, and the glass is then heated, the air sucked out by the blowing tube, and the whole becomes afterwards encased in clear glass. So perfect is the welding of the mass, that it is impossible to detect the points of junction, and the filigree work appears almost as if it floated in the middle of the clearest water. In the mille-fiori, or star-work, the pieces are arranged in a more regular manner, but the general principle of manufacture is the same.

Mosaic glass appears to have been long known. Specimens of beautiful design and colour exist in the British Museum. The art appears to have flourished among the Romans, who were accustomed to wear as ornaments small pieces of glass beautifully executed in Mosaic. These gems, for such they were then esteemed, were wholly formed of minute threads of glass of different colours ranged vertically, side by side, in a prefigured design. When submitted to heat sufficient to fuse the whole, the four sides being at the same time pressed together, so as to exclude the air from the interstices of the threads, the whole is united to form a homogeneous thick slab, which, if cut into veneers at right angles, or laterally, will yield a number of slabs or lengths of the same uniform design. Even pictures

were formed in this manner. This beautiful art is no longer practised.

Another curious art practised by the Venetian glass-blowers, was the manufacture of what they called Vitro di Trino. This was made in the following way:—A ball of clear flint-glass was gathered on the end of the blowing tube, and then blown into a brass mould, on the sides of which were arranged pieces of white glass cane, in a vertical direction. The white strips unite themselves to the surface of the glass, which is then warmed and slightly twisted, so as to give the white lines a spiral direction. The end is then opened, and a cup is formed. In order, however, to complete it, another cup is formed, which is placed within the first, and the two are united together by heat. The appearance of the glass thus produced is very interesting. It is seen to be crossed spirally by two sets of white lines which intersect each other, and at every intersection a minute bubble of air is entrapped, giving the vessel the most singular appearance.

The Venetian frosted glass is still more singular. One would suppose the whole mass were in the act of dropping into a thousand fragments. The vessel appears, in fact, shivered to pieces, yet it will hold fluids, and, still more strange, when struck it will ring as clear as an ordinary glass, showing that in reality its texture is entire and uncracked. This remarkable kind of glass is made thus. A lump of clear glass is gathered on the blowing tube, and expanded by blowing, while at nearly a white heat; it is then suddenly plunged into cold water. If it be then immediately turned round and blown out, the crystals formed by the chilling of the surface are separated from each other, and thrown outward, while the interior of the vase is quite entire. It is then formed into shape, separated from the blowing tube, and finished by annealing.

One of the most beautiful and interesting departments of the art of the glass-maker consists in imparting to glass a variety of transparent colours. This is accomplished by adding to the usual ingredients of glass the oxides or carbonates of certain metals, which have the quality of imparting to the structure of the glass a quality, in virtue of which it absorbs certain constituents of the solar light, and transmits or reflects others.

Iron, copper, cobalt, manganese, gold, and uranium, are the metals chiefly used in imparting colour to glass. The shades of green are produced by the oxides of iron and copper combined in different proportions, the yellow tints being due to the iron, the blue to the copper, and the green to their combination. A dull yellow-coloured glass is produced by the carburet of iron; a blue glass by the oxide of cobalt; the purple is produced by the oxide of manganese; and the varieties of rose and ruby glass by the oxide of gold. The oxide of uranium produces the topaz colour; and the same metal, with the addition of a small quantity of copper, produces a lively emerald green. It is not, however, only the colours of transparent gems which can be represented by this artificial process, but even the opaque stones are imitated. Glass is rendered opaque by the addition of arsenic, and a very peculiar colour of opal is produced by the addition of phosphate of lime.

But of all the processes introduced by modern art into glass-making, one of the most interesting and beautiful consists in the combination of different colours in the same object, which, combined with subsequent cutting, produces infinitely various and interesting effects. Nothing can be more simple than the process by which these effects are produced. The object being formed first in transparent and colourless glass, and this glass being allowed to cool until it acquires solidity and consistency, it is dipped for a moment in a pot of

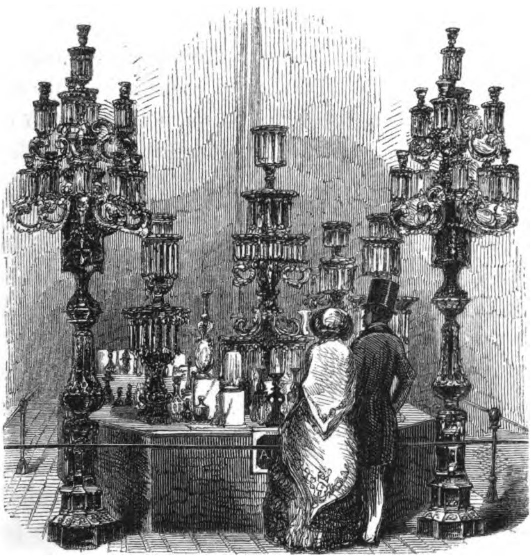
coloured glass in a state of fusion, and being suddenly withdrawn, it carries away upon it a thin coating of coloured glass, which immediately hardens upon it, and becomes incorporated with it. The article is then shaped by the processes of the glass-maker; and if it be afterwards cut, those parts which are cut will disclose the clear transparent glass, the parts not cut remaining coated with the colour. It is by this process that all effects which are seen in the ornamental articles, which consist partly of coloured and partly of clear glass, are produced. It is evident that an infinite variety of figures may thus be formed, the outlines of which will be marked by the boundaries of the coloured and clear glass.

Two or more colours may in the same manner be combined on the article, after being coated as already described, since glass of one colour may be dipped in the same manner in glass of another colour in a state of fusion, so as to take up another coat of a different colour; and by cutting the surface of such objects to different depths, varieties of effects may be produced, in which two or more colours may be combined.

The only difficulty in this process, is the proper union of the several coatings of coloured glass, because if any difference exists in what glass-makers call the "temper" of the metal, the unequal contraction during the process of annealing may be such as to cause fracture. This is what is called casing glass; and a large proportion of the ornamental glass now in use, both in this country and on the Continent, is cased glass. The Bohemian glass-makers particularly excel in this art. Some of the splendid specimens shown in the cut on the next page were of this description of glass.

Much has been done of late in the way of ornamenting glass manufactures, and two of the most successful plans are those of silvering the inner surface, and also of engraving on the under surface of the glass. In the

ingenious method of silvering, introduced by Messrs. Mellish and Varnish, the glass is double; the object of this being to enable the patentees to fill the inside with a solution of nitrate of silver, to which grape sugar is added, when all the silver held in solution is deposited in a beautiful film of revived silver over every part of the glass. This silvering on the interior wall of the glass (globes, vases, and numerous other articles are shown to be susceptible of the process) has the property



of reflecting back through the glass all the light which falls on the surface—whereas ordinarily some is transmitted, and only a small portion reflected. This exalts many of the colours in a striking manner; and not only does it exalt the colours, but the dichromism of the glass is curiously displayed. Much of the red and yellow glass thus assumes an opalescent tinge of blue, which, in some examples, is not unpleasing. Some of

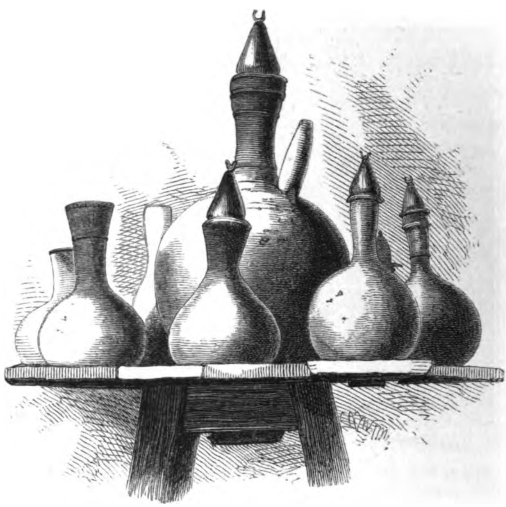
the coloured examples of this process are very pleasing, but pure white glass—the beauty of which is its transparency—is not in any respect improved by silvering.

The engraving on glass after the method of Mr. Kidd is exceedingly beautiful. This process for illuminating, embroidering, and silvering flat surfaces, is a sort of combination of ordinary engraving with the silvering of Messrs. Mellish. All the designs are cut on the under face of the glass, and then being silvered, are thrown up in a very pleasing manner, producing an optical deception of an interesting character.

The repeal of the Excise duties on glass-making has produced the most remarkable results in the general progress of the art. For many years the British manufacturer was so far behind the foreign, that all the best kinds of glass were obtained from the Continent. He could make no experiments without the supervision of the Customs officer, and was often compelled to pay duty on articles absolutely useless to him in a commercial sense. Scarcely, however, had a year elapsed, before the repeal of the duties led to the most evident improvement in the products, and it may now be safely asserted that neither in quality, colour, or artistic execution, are we inferior to other countries, and in many respects, and particularly in the useful articles, we far surpass them. In one particular we are still behind, and that is in the colour of our crown glass. The foreign crown glass is clear, like crystal, while ours is always tinged with a disagreeable greenish yellow colour. This is due in great measure to the impurities of our sand, and could this be procured free from metallic impregnations, we could have no difficulty in manufacturing colourless crown glass. The Americans are making very good and colourless glass.

The art of the potter, although very distinct from that of the glass-maker, may be conveniently studied by its

black pots, made in the simplest way, and rendered impervious to water by being exposed during the baking to a very strong and dense smoke, which penetrates their substance, and answers the purpose of glazing; and from the royal porcelain works of the same State were contributed magnificent objects, of beautiful material and execution. Among the pottery utensils which attracted much notice were those sent by the Bey of Tunis, and represented in the engraving. These articles were made of a clay called Kench earth, were of a fawn colour, and



of very simple design; they were unglazed, and were for the purpose of cooling water, the evaporation of which from the outer surface produces a considerable amount of cold, which is communicated to the fluid within. Vessels for similar purposes are extremely common in the East, and represent a very simple state of the art, for they are merely formed of clay, roughly prepared and baked. A still more interesting collection was that obtained from China. It combined a complete collec-

tion of the materials used for making porcelain in the imperial works, and also specimens of the various colours used for ornamenting it.

Our object in the present notice of pottery as an art will be best accomplished by simply describing the present methods adopted by our best makers, and in noticing several of the interesting and remarkable improvements introduced into it within the last few years. In so doing we shall be guided chiefly by the excellent

TUNISIAN POTTERY.

published account of this art, written by Mr. Thomas Battam, and published in the official Catalogue of the great Exhibition. We will commence, then, with the preparation of the clay.

The clays used are those of Cornwall, Devon, and Dorset. The Cornish is the best quality, and is technically termed by potters "China clay," and enters very extensively into the composition of the best kind of ware. It is the decomposed felspar of the granite, and is prepared by the clay merchants themselves in Corn-

wall, prior to its being sent to the potteries. Huge masses of white granite abound in Cornwall, which is in some parts found partially decomposed; and when this is the case, the mineral is raised and prepared for the potter's use, it having been discovered by Mr. Cockworthy, of Plymouth, in 1765, that it furnished the true kaolin, and also the "petunsee" of the Chinese.

The following is the method of preparation:—The stone, having been broken up by a pickaxe, is laid in a stream of running water. The light argillaceous parts

FINE WARE OF TUNIS.

are thus washed off and kept in suspension; the quartz and mica being separated, are allowed to subside near the place where the stone was first raised. At the end of these rivulets are a kind of catchpools, where the water is at last arrested, and time allowed for the pure clay with which it is charged to form a deposit, which being effected, the water is drawn off; the clay is then dug up in square blocks, and placed upon a number of strong shelves, so fitted as to allow a free circulation of air, in order that the clay may be properly dried. Thus prepared it is extremely white, and, when crushed,

forms an impalpable powder. It is forwarded to the potteries under the name of China clay.

About 1,757 tons of this clay were exported from Charlestown, a port near St. Austle, to the potteries in 1809. In 1826 the export had increased to 7,090 tons from Charlestown, 400 tons from Pentuan, 30 from Porthleven, and 18 tons from St. Michael's Mount. Of late years the demand has greatly increased, and China clay is not now used in the manufacture of porcelain only, but many thousand tons are annually employed in calico bleaching establishments and in paper manufactories, the object being in both cases to give an artificial body to these substances. At least 20,000 tons of the Cornish and Devonshire China clays are now annually prepared.

In addition to this artificially-prepared China clay, an inferior kind is raised at Bovey Tracey, probably to the amount of about 25,000 tons annually.

Besides the clay thus prepared, flints are also largely used in this art. They are obtained from the chalk rocks; and, in order to fit them for the potter's purposes, they are first burnt in a kiln, and afterwards ground to an impalpable powder under water.

For the commoner articles a variety of different kinds of clay are employed. These, of course, differ in purity and also in chemical combination, but in all, silica and alumina are the principal constituents. The following analysis of a few of the clays employed by the potter will convey some general idea of their composition:—

	Silica.	Alumina.	Lithia.	Lime.	Iron.
Common Pottery Clay*...........	60	33	—	3	3
Blue Ball Clay*.....................	64	35	—	—	1
Cracking Clay*	68	31	—	—	1
Cornish China Stone...............	68	16	14	—	2
Ditto Clay	71	20	2	—	—

* These clays are usually found united with the coal measures.

The materials thus derived require a careful preparation before they are fit for the purpose for which they are intended. They are carefully reduced to the finest state of subdivision, and the paste they form is as smooth as possible to the touch.

The next stage is the "mixing," for which purpose the different "slips" (the technical term for the fluid clays, &c.) are successively run off into the blending reservoir, against the inner side of which are "gauging rods," by which the necessary proportion of each material is regulated. The mixture is now passed into other reservoirs, through fine sieves of "lawns," woven of silk, and containing 300 threads to the square inch. A pint of slip of Dorsetshire or Devonshire clay weighs 24 ounces, of proper consistence; of Cornish clay, 26 ounces; and of flint, 32 ounces. Finally, the slip is conveyed to a series of large open kilns, heated underneath by means of flues, and about 9 inches deep. The excessive moisture is thus evaporated, and in about 24 hours the mixture becomes tolerably firm in substance. It is then cut into large blocks, and conveyed to an adjoining building to undergo the process of "milling." The mill is in the form of a hollow cone, inverted, with a square aperture or tube at the lower part. In the centre is a vertical shaft, set with broad knives. When this shaft is in action (worked by steam-power), the soft clay is thrown in, and forced downwards, being alternately cut and pressed until it exudes from the aperture at the bottom, in a perfectly plastic state, and ready for the hand of the potter.

The potter's wheel is probably one of the most ancient manufacturing machines that we possess. When the art was almost in its simplest state, the potter's wheel was in use to form the cups and pots then made, and subsequent progress in other respects has not altered the manipulative processes, for the same apparatus is in use at the present time. It is, in fact, one of those completely successful

and simple forms of machinery which are incapable of improvement. It consists merely of a vertical spindle, driven by a band from a driving wheel, and having at the top a disc of wood, upon which the clay is placed. The potter takes the soft mass in his hand, places it on the disc, which is then made to revolve rapidly, and gives it a circular form merely by the skilful pressure with his hands, smoothing it by a simple tool of horn or slate. The mass, in a wonderfully short space, receives the required shape, becoming a teacup or a basin, and is then cut off by a brass wire, and passed on, while a fresh mass takes its place. In this way the potter, to use the image and beautiful language of the Word of God, exercises his "power over the clay to make one vessel to honour, and another to dishonour." No figure could better express an infinite power of choice, and of adaptation of objects to any end desired by the maker of them; for the manipulations of the potter are more like acts of creation than of manufacture. The operation is called "throwing," and the articles when sufficiently dry are transferred to the hands of the "turner." The duty of this artist is to form the curves more truly and sharply, and to impart a uniform smoothness and polish to the surface. This process resembles that of ordinary wood turning, but, from the nature of the material, is executed with much greater facility. The vessel is fitted upon a block, or "chuck," attached to the lathe, and the turning is performed by thin iron tools, few in number and simple in form.

Articles of this class which require "handles" are passed from the lathe to the "handler." These useful adjuncts are made by pressure in moulds of plaster of Paris, and after being sufficiently dried, are fixed on the vessel with "slip," or fluid clay. The adhesion is so immediate, that in most cases the article may be lifted by the handle before it has left the hands of the ope-

rator. When the handle is fitted, the superfluous slip which exudes from the junction, after the parts have been pressed together, is removed with a sponge, and the surfaces worked together and smoothed round with a small tool; the article is then finished, unless a "spout" or "lip" is required, as in the case of teapots, jugs, &c. These are made and attached in the same manner as "handles." Larger articles are also made in this way, by being pressed in a mould.

The next and most interesting process in what we may term the first stage of the art—that is to say, before the material is exposed to the heat of the oven—is entirely different from the preceding kinds. It is a sort of coating, and is used for the production of ornamental objects. To this, however, we shall again immediately advert.

After the clay has left the hands of the potter, it is in a fragile state, and quite unfit for actual use. The assistance of an intense heat is now necessary, in order to give it solidity. This is effected in a large oven; but before the articles are exposed to it, they are gradually prepared for its endurance by being placed in what is called a greenhouse, in which a moderately elevated temperature is kept up. When sufficiently prepared, they are then transferred to the intenser influences of the ovens. The objects are placed in boxes made of a peculiar kind of clay, and called "seggars:" these protect them from dust and smoke. A little pounded sand or flint is sprinkled between them, and the articles are then placed one above another in the seggars, and carried to the oven.

The ovens are not exposed to the open air, but are enclosed in what is called a hovel. The hovels in which the ovens are built form a very peculiar and striking feature of the pottery towns, and forcibly arrest the attention and excite the surprise of the stranger, re-

sembling as they closely do a succession of gigantic beehives. They are constructed of bricks, about 40 feet diameter, and 35 feet high, with an aperture at the top for the escape of the smoke. The "ovens" are of a similar form, about 22 feet diameter, and from 18 to 21 feet high, heated by fire-places, or "mouths," about nine in number, built externally around them. Flues in connexion with these converge under the bottom of the oven to a central opening, drawing the flames to this point, where they enter the oven: other flues pass up the internal sides to the height of about four feet, thus conveying the flames to the upper part.

When "setting in" the oven, the firemen enter by an opening in the side, carrying the seggars with the ware placed as described. These are piled one upon another from bottom to top of the oven, care being taken to arrange them so that they may receive the heat (which varies in different parts) most suited to the articles they contain. This being continued till the oven is filled, the aperture is then bricked up. The firing of earthenware bisque continues sixty hours, and of china forty-eight. The quantity of coals necessary for a "bisque" oven is from 16 to 20 tons. The ware is allowed to cool for two days, when it is drawn in the state technically termed "biscuit," or bisque, and is then ready for "glazing," except when required for printing, or a common style of painting, both of which processes are done on the "bisque" prior to being "glazed." The glazing is effected also entirely by heat, and consists, in fact, of a thin varnish of melted material, covering the ware, and penetrating a little way into its substance. The preparation of the glaze consists of a mixture of Cornish stone, powdered flint, white lead, glass, whiting, &c. These are ground to the finest state of division, and are mixed with water to the consistence of milk. The articles to be glazed are simply dipped in this fluid,

and then transferred after drying to the glazing oven, the heat of which fuses the materials of the glaze, and causes the object to be covered with a hard transparent glassy varnish.

The method of attaching design or ornament to the surface of china ware is twofold, either by transferring it from paper, or by giving the ornament by hand. The transference of the design is very simple, and is the ordinary method employed for ornamenting table ware. The design is first engraved on a copper plate, and is printed on very thin paper, made purposely for this art, and generally obtained from old colliery ropes. The ink used is formed of various metallic oxides, mixed with oils and resin, and sinks into the surface of the ware which is not as yet glazed, and the article is then transferred to an oven, where the oil of the ink is destroyed by heat, and the design left in its true colour on the surface. Printing is also effected after the article has been glazed, where very delicate designs are required. The process is very similar, but a surface of glue is used to take off the impression from the copper plates, and the colour is dusted on, and not mixed with the oil.

Gilding is effected by the gold being laid on in a state of minute subdivision with a pencil, and is mixed with oils and turpentine, and appears as a metallic surface after being exposed to the heat of the ovens. The after brilliancy is given to it by burnishing and careful polishing. The higher kinds of artistic decoration, such as enamel painting, are effected by persons long trained in the pursuit, and the design and colours are fixed upon the porcelain by firing, as before. The success, however, of this art is very uncertain, in consequence of the continual changes of colour induced by the heat of the oven.

One of the most important and beautiful develop-

ments of the porcelain manufacture has been made, within the last few years, by Mr. Battam, in the introduction of the beautiful material called Parian. In almost every shop-window, exquisite copies of fine statues are exhibited, the colour and texture of which is almost equal to that of pure marble. This admirable material was first prominently brought under notice by the Art Union of London, which gave, as one of its prizes, a copy of Gibson's Narcissus, formed of it; and it has since become extremely popular, an immense trade in small groups and statuettes having sprung up.

The principal ingredients in this composition are kaolin, felspar, and silica, ground and mixed together in the ordinary method adopted in the general processes of this manufacture. It is prepared for the use of the figure makers in a state technically called "slip," about the consistency of thick cream. In this state it is poured into the different moulds forming the sub-divisions of the figure or group, which, being made of gypsum (plaster of Paris), rapidly absorb a portion of the moisture, and reduce the coating immediately next the mould to a semi-clay state, of a sufficient thickness for the "cast," when the superfluous "slip" is then poured back from the moulds. This cast remains in the mould for some time at a high temperature, which, by causing still further evaporation, gradually reduces the "slip" to a state of "clay," sufficiently firm to support its own weight when relieved from the moulds, and to bear the necessary pressure of the handling without injury. The various parts (and in some groups there are as many as fifty) are then delivered from the moulds. They have then to be repaired, the seams caused by the junction of the moulds to be cleared off, and the whole put together.

The parts are attached together with some of the "slip," as originally used for the casting, the surfaces to

be joined together being either dipped in it, or a coating of it applied with a pencil: this causes perfect adhesion with a very slight pressure. Much depends upon the skill with which these junctions are executed, and on the neatness with which the sections of the moulds are made to fit, as, upon due attention to these particulars, the greater or less degree of prominence in the "seams," which so often disfigure pottery castings, entirely rests. With great care and tact, it is possible to render these "seams" so trifling as, even upon a close examination, to be scarcely perceptible.

The "slip" in this case is merely required to soften the surface of the clay on those parts which have to be united, just sufficiently to cause adhesion; and all that is used beyond what answers that requirement is not only superfluous but detrimental, by moistening the edges of the parts to which it is applied so much that they become pliant, and, yielding to the pressure while being attached, distort the outline; and also, by causing unequal shrinking during the process of "firing," the junctures become evident and unsightly.

The figure or group thus made remains two or three days, during which time it becomes sufficiently dry for the oven. It is supported by props, made of the same material, so arranged as to bear a portion of the weight, and to prevent any undue pressure, which might cause the figure to sink in the "firing."

It is then placed in the oven on a "seggar," the usual case to protect the ware from the flames, and submitted to a heat of 60° of Wedgwood's pyrometer.

This operation, which occupies from sixty to seventy hours, is effected very gradually. Small pieces of ware termed "trials," expressly made for the purpose, are occasionally drawn from the oven, to ascertain the progress and degree of heat.

The fires are then withdrawn, and the oven allowed

to cool very gradually, as too sudden a change of temperature would cause the ware to crack. When sufficiently cool, the figures are drawn out, and the seams, which, although perfectly cleared off in the clay state, will again partially rise during the process of firing, are then rubbed down, and the figures again submitted to a still higher degree of heat than in the first firing. The figures are placed on a bed of sand in the latter firing, instead of being "propped" as in the former, as this bed more equally supports the figure; and the clay having been once fired, the surface is not injured by being in contact with the sand. It could not be used when the figures are in the clay state, as it would resist the contraction of the material, and cause the figure to be shattered to pieces. It is often necessary to fire the casts three times, a peculiar degree of heat being required to produce the extreme beauty of surface which the finest specimens present.

The total "contraction" of the figures, from the mould to the finished state, is one-fourth. The contraction of the "slip" with which the mould is charged, to the clay state in which it leaves the mould, is one-sixteenth. Again it contracts another sixteenth in the process of drying for the oven, and one-eighth in the process of vitrification; so that a model of 2 feet high will but produce a fired cast of 18 inches.

Now as, to ensure a perfect work, it is necessary that this "contraction" should equally affect the whole of the subject through all its relative bearings and proportions, it will be immediately apparent that there is considerable hazard in its execution.

Such is the substance of Mr. Battam's account of the manufacture he has been the ingenious inventor of, and it must be acknowledged that a most valuable and important era in the potter's art has been thus commenced. Ornaments in "Parian" have been extensively intro-

duced in upholstery decorations, and in gas-fittings for drawing-rooms; and, from their beautifully clean appearance, and the variety of form the material is capable of assuming, this application of it is likely to become as popular as its higher uses for the purposes of art.

Another very interesting novelty in pottery has also been introduced by Mr. Battam. It is a reproduction of the exquisite vases of the ancients, some of which were employed in their sepulchral ceremonies. The originals of these vases were of beautiful design and of great harmony of composition, and the modern reproductions can scarcely be distinguished from them. The material used is a red clay, upon which the figures are painted in a very dark pigment, and burnt in.

A very remarkable invention has recently been introduced into this art, by Mr. Prosser in this country, and M. Bapterosses in France. Mr. Prosser appears to have been the inventor of the process to which we allude, but it was subsequently perfected by M. Bapterosses, in Paris. It is the production of objects by the mere pressure of the powdered material in a powerful press. M. Bapterosses has carried on this process on a large scale, in the manufacture of buttons, and Mr. Prosser in that of tiles and slabs. It is found that sudden and severe pressure upon the damp powder causes it to cohere, and form a solid and compact mass of beautiful texture and polish. Thus a polished button is produced, at one blow of the press, out of a little heap of powdered clay! In the same manner, a tile of any shape, or a slab, is, at a stroke, formed out of the loose material at the side of the workman. If necessary, they can then be ornamented, and, after being dried, glazed, and fired, are fit for use. M. Bapterosses exhibited some of the interesting products of his method in 1851.

Another method of producing tiles is what is called the encaustic method. The clay is poured in a mould,

which leaves indentations on its surface, and, when it is fit to receive it, a quantity of fluid clay of another colour is poured into these indentations. The surface is afterwards smoothed down, and the tile appears with a ground of one colour and a design of another. It is subsequently fired, and slowly cooled. These tiles are in great demand at present, in consequence of a revived taste for pavement formed by them.

A pleasing variety of effect has been very lately introduced in this manufacture by the Baron du Tremblay. It consists in flooding coloured but transparent glazes, over designs stamped in the body of the ware. A plane surface is thus produced, in which the cavities of the stamped design appear as shadows of various depths, the parts in highest relief coming nearest the surface of the glaze, and thus having the effects of the lights of the picture. Perhaps there is no process in the ceramic art by which, at so cheap a rate, designs of high artistic merit can be reproduced, in the most harmonious tinting, for articles of common use.

The coarser kinds of pottery were exhibited in 1851, in the enormous chemical apparatus of Messrs. Doulton & Watt, of Lambeth Potteries. And this manufacture was also illustrated by the exhibition of the colossal wine jars of Spain, one of which is shown in the engravin on the next page. In the production of these monstrou specimens of the potter's art, it is evident that the ordinary method of throwing is inapplicable. They are, in fact, built up with slabs of clay, and then smoothed and brought to a true figure, and afterwards fired in an oven.

The Great Exhibition contained one of the most complete collections of porcelain and pottery ever brought into one building, and formed a true type and living picture of the present state of this interesting and important art throughout the world. From the States of

immense value, and were wonderful specimens of the perfection of ceramic art. Among other interesting objects shown, were the fine paintings of her Majesty and Prince Albert, on large slabs of porcelain, shown close to the crystal fountain. On the whole, it was a wonderful display of the condition of this art; and to any one who had opportunity to study it, it presented a collection of illustrations of its rudest and of its highest states of development, which will probably never again be equalled.

CHAPTER IX.

HARDWARE MANUFACTURES.

In bringing the present work to a close, the writer has felt that a notice of that remarkable department of industry—the hardware trade—appeared necessary, in order to complete our survey of the industrial arts of our century. For so widely useful is this particular manufacturing art, and so intimately connected with the common wants of mankind, that it may be taken to form one of the most prominent features in the field of industrial activity. Tins, saucepans, tea-trays, kettles, fire-irons, and steel pens, which are all included under the general subject of Hardware, are not less important, either to our use or comfort, than calicoes, silks, and woollens. And a vast trade has in the course of the last half-century sprung up in the production of these and similar articles, giving occupation to tens of thousands, and administering to the wants and comforts of millions. With this large and interesting topic we shall occupy the remaining pages of our volume.

Birmingham is the great centre of hardware manufactures, and has been amusingly described in the following terms by the historian, Mr. Hutton:—"The manufacture of iron in Birmingham," he writes, "is ancient beyond research; that of steel is of modern date.

From this warm but dismal climate issues the button which shines upon the breast, and the bayonets intended to pierce it; the lancet which bleeds the man, and the rowel which bleeds the horse; the lock which preserves the beloved bottle, and the screw to uncork it; the needle, equally obedient to the thimble and the pole."

From the careful researches of a more modern writer,* we obtain a little more explicit information on this subject. The trade of the Birmingham hardware manufacturers is divided into two great branches, which have received the curious names of the Heavy and the Light Steel Toy-trades. It is difficult to account for the application of this term, for it certainly cannot be said that the articles made by either the Heavy or the Light Steel Toy-makers are of the nature of playthings, since they include the most extraordinary variety of objects, from the movable piece of iron used as a door-scraper, to the tomahawk of the Indian—neither of them likely to afford much amusement. Nearly six hundred different articles are included under the Heavy Steel Toy list.

This list includes, according to the index to the pattern-book of one of the principal manufacturers, the tools and implements used by carpenters, coopers, gardeners, butchers, glaziers, upholsterers, farriers, masons, plumbers, coachmakers, millwrights, mineralogists, saddlers, harness-makers, tinmen, shoemakers, weavers, wheelers, and wire drawers; besides bodkins for tailors, spatulæ for surgeons, ships' augers, and a whole multitude of minor and most heterogeneous articles—such as corkscrews, sugar-tongs, sugar-nippers, boot-hooks, button-hooks, door-scrapers, calippers, compasses in countless variety, from three inches to twenty-four inches in length, pinking-irons, curling-irons, dog-collars, dog-chains, dog-whistles, tweezers, lobster

* Vide *Morning Chronicle*—Labour and the Poor, 1851.

crackers, cheese-tasters, champagne-nippers, tinder-boxes, and tobacco-stoppers. Among other strange articles formerly included under the term of steel toys, were tomahawks for the North American Indians; but this article is no longer in demand, though a few specimens are preserved in the town as curiosities. The great distinction between the heavy and the light steel toy seems to be, that the one is useful, and the other ornamental; that the heavy steel toys are used as tools in trades, or in the household; and that the light steel toys are devoted almost exclusively to the adornment of the person. The articles which give employment to the largest number of work-people in the heavy steel toy trade, are hammers and shoemakers' tools. Of hammers there is the most extraordinary variety both of size and shape, and the weight varies from an ounce to several pounds. It has been stated that not less than 300 varieties of hammers are made in Birmingham, each adapted to some particular trade. Thousands of shoemakers' tools are exported to the Colonies and the United States, and an immense trade is also done in the humble article of sugar-nippers! "Some firms," observes the writer to whom we have adverted, "are renowned for the peculiar excellence of their shoe-pincers, which fetch a higher price in the markets of the world than the shoe-pincers made by any other firm; others, again, are celebrated for their hammers, others for hatchets; while another has such a reputation for bricklayers' trowels that competition with him is all but useless. Some idea may be formed of the immense demand for these and similar articles, many of which require to be put up in brown paper, from the fact that many of the manufacturers use five tons of paper per annum merely for wrapping up!"

The most curious variety of articles are certainly comprised in this manufacture, as may be imagined from

the preceding list. It becomes, in fact, difficult to say what is not included in it. Among other things are even the instruments used by housebreakers! Many of these implements, it is true, are the ordinary tools of honest mechanics, such as the centre-bit, the crowbar, the wedge, &c. But in addition to these, are the less respectable tools called "steel-bars," "gouges," "ripping chisel," "picklocks," "skeleton keys," and "pocket-jacks." This trade is of some extent, and its best customers are said to be the London thieves. It is not, of course, to be understood that any respectable manufacturer makes the instruments just named, but even they are said to receive occasionally an order for an odd-looking instrument, which they suspect to be intended for no very legitimate purpose, although they have no means of ascertaining the fact.

At Birmingham, however, are also produced those instruments as formidable to the housebreaker as are his tools to the honest man. Handcuffs, fetters, and leg-chains, are made in great numbers in Birmingham, which are sent for the use of all the prisons in Great Britain. Four manufacturers are engaged in this trade, much of which is for exportation. It has been stated that even thumb-screws are occasionally made in Birmingham, but not, of course, for use in this country. Some of these are exported to the southern States of America.

The light steel toy-makers are more numerous than the heavy steel makers; and a most extraordinary variety of articles is produced by them, as may be imagined from the list which follows, and which embraces the objects made by one house in this trade. It includes chatelaines, watch-chains, neck-chains, keys, seals, purses, purse-springs, slides and beads, reticule springs and fittings, waist-buckles, knee-buckles, latchets, dress-swords, steel buttons for court suits, button-

hooks, boot-hooks, nut-crackers, cork-screws of all kinds, steel-tassels, tags and fringes, bodkins, stilettos, swivels, brooches, spectacle-frames, knitting and netting implements, necklace snaps, steel snuffers, bracelets, pocket-book locks, snaps, &c. In the production of these articles, however, our manufacturers experience a very active opposition on the part of the French makers, who are able to manufacture certain articles at a price so extraordinarily below ours, that competition is useless. One of the light steel toy-makers has stated this fact in a striking manner:—

"The one article of small beads for purses supplies an illustration of the French superiority. The Birmingham manufacturers allege that they cannot produce such beads under 6*d.* a gross; while they can be imported from France and sold in Birmingham at 2½*d.* for a dozen gross. In the production of steel watch-chains, the French have also an advantage over the English; and an eminent maker of light steel-toys, in showing an article of this kind, large and massive to suit the present fashion, but beautifully polished and wrought, alleged that he could import it for 3*d.*, but could not manufacture one in Birmingham for six times the money. The French makers are quite aware of their superiority, and jealously preserve the secret of the processes they employ, at least from the knowledge of English workmen or employers, or those likely to be in their confidence."

The Great Exhibition also contained specimens of hardware made by Tunisian artificers, shown in the cut, which, though very unlikely to compete with our own, are interesting from the peculiarity of their designs.

It is stated, in fact, that in some villages in France, these beads are made by the children, and strung together for sale.

The manufacture of buckles was formerly a most

lucrative and important part of this trade, but it has entirely gone down. Snuffers-making was also an excellent business, but it has been nearly extinguished by the patent candles! Altogether, this trade is one of much interest and variety, but it is also subject to many fluctuations, and often is greatly under the influence of the caprices of fashion.

Adverting now to particular departments of the general class of hardware manufactures, we shall select a few features in this industrial group which will give an instructive view of the ingenuity characterising its several subdivisions. The manufacture of steel pens is one of these, and has risen into great importance within the last twenty years. The introduction of the metallic pen does not date further back than about thirty years ago, and on its first being submitted to public approval

each pen was charged at sixpence. At the present moment one hundred and twenty-four can be purchased for the same sum, and of equal, if not superior, quality. Birmingham has from the first been distinguished as the seat of this useful manufacture, and there are now several immense works, where millions of steel pens are annually produced. Mr. Gillott of that town established the first steel pen factory on a large scale, and the works now carried on in his name are the largest in the world for this purpose. Upwards of 1,000 persons are occupied at these works, the majority of whom are females. In May, 1851, the number of pens made there in the preceding year amounted to upwards of 180 millions, and the weight of sheet-steel consumed in their manufacture to not less than 268,800 lbs. or 120 tons. The manufacture is conducted in the following manner:—A strip of thin sheet-steel, of the proper width and thickness, is first prepared, by careful rolling and annealing. In this state it is ready to be cut into pens by means of a press, in which are fitted the proper tools for cutting out the "blank." The use of the press is to give a regulated amount of pressure to the tools fitted to it. These presses are worked by women, who are so dexterous that the average product of a good hand is 200 gross, or 28,000 per day of 10 hours. Two pens are cut out of the width of the steel, the broad part to form the tube; and the points are cut to such a nicety, that there is but little waste. The "blanks" are now taken to be pierced, and here the little central hole and the side slits are cut by another press. These semi-pens are now placed in an annealing oven to make them softer, after which they are "marked," by the aid of a die worked by the foot, which stamps the name of the maker on the back. The half-finished little instrument is then placed in a groove, and by a machine converted from a flat into a cylindrical form. This is called

"raising" the metal. The pens are again placed in the "muffle," packed in small iron boxes with lids, and heated to a white heat. They are then withdrawn, and suddenly thrown into a large vessel of oil, where they acquire a brittleness that makes them almost crumble at the touch. The next process is "cleaning," then follows "tempering," which restores the pens to the required elasticity, and is accomplished by placing them in a large tin cylinder, open at one end, and turned over a fire in the same manner that coffee is roasted. The heat changes the colour of the pens—first grey, then straw-colour, next to a brown or bronze, and lastly to a blue. Still there is a roughness to be removed from the surface, which requires the pens to be placed in large tin cans, with a small quantity of sawdust. These cans are horizontally placed in a frame, and made to revolve by steam, the pens rubbing against each other, by which means they are cleaned. After the "scouring" process, (which consists in placing the hardened pens in an iron cylinder, which is filled with pounded crucible, or other abrasive substance—the whole revolves by power, and the friction produces a bright clean surface on the pen,) they are taken to the "grinding-room," where each individual pen is ground at the back in two ways, at right angles to each other, or rather over each other, the quality of the pen very much depending upon this operation. By the aid of a pair of nippers, the girl takes up the pen, holds it for a moment or so on a revolving "bob," and the grinding is over. Now follow the pen to the "slitting-room," where it is placed in a press, where the process is instantly effected. The pens are next examined, and sorted according to their qualities; after which they are varnished with a solution of gum, when they are considered ready for sale.

For some time the introduction of machinery in the

steel pen manufacture appeared attended with insuperable difficulties, for there seemed no possibility of completing a steel pen by anything like a continuous process. This difficulty has, however, been surmounted, and in the Great Exhibition there was shown a machine now in great use, which effects this object. This machine is the invention of Messrs. Hinks, Wells, & Co., of Birmingham. This most ingenious engine is entirely self-acting. It receives the steel as a flat ribbon, and cuts, pierces, and side-slits two pens at one stroke, performing six processes at once. In order to illustrate the perfection with which this machine operates, some very minute steel pens were exhibited, a gross of which only weighed a little over 30 grains, and was capable of being enclosed by a Barcelona nut-shell. At the same place were shown some enormous pens, one of them weighing several pounds, and certainly never intended for use among the occupants of our globe.

The history of this manufacture is interesting. In 1820 the first gross of steel pens was sold, at the rate of 7*l.* 4*s.* the gross. In 1830 they had fallen to 8*s.*, and the price gradually fell, until it reached the sum of 6*d.*, which is its present limit. One of the Birmingham factories produces at the rate of 960,000 per day, or 289,528,000 per annum. The total production of the Birmingham makers amounts to at least 1,000 millions per annum. The cheapest pens are sold at 2*d.* per gross wholesale, and the most expensive at 5*s.* or 6*s.* In the manufacture, the steel assumes the most wonderful variety of texture. At first it is soft as lead, afterwards it becomes as brittle as glass, and finally it is tempered to a state of elasticity as nearly as possible approaching that of the quill pen.

In the United States a considerable manufacture of metallic, and especially of gold pens, is carried on.

About one million are made annually in New York, and are pointed with iridium, an extremely hard metal, found with platinum. The manufacture resembles that of steel pens, but the points are put on by soldering. It is stated that 800 lbs. of gold are used every year in America for this purpose.

In connexion with the steel pen manufacture, a considerable trade in pencil-cases, pen-holders, and little articles necessary to the use of the steel pen, has sprung up. Some of the Birmingham factories turn out enormous quantities of ever-pointed pencil-cases, adapted for steel pens also; and there was at one time a great rage for these pencil-cases in their most complicated form, in which they were made to combine letter-weights, toothpicks, coin-detectors, mechanical calendars, and other things, all in one article.

A number of other fancy articles for the writing-table are also made at Birmingham, such as letter-weights, ink-bottles, taper-stands, match-boxes, &c. These are often made at one factory, where medals are struck, buttons are made, metal boxes of all kinds, together with a wonderful variety of minute objects of different descriptions. The showy little metal boxes called Vesta boxes, are made of thin metal tubing, ornamented in the lathe, or by stamping, and then coloured by lacquering. In some boxes the lacquer is cut through in an ornamental manner, so as to show the metal beneath. These boxes are remarkably cheap, and if not very artistic or elegant, are curiously resplendent in colour, and are well adapted for the uses to which they are applied.

The manufacture of pins is also carried on to a very large extent at Birmingham. These minute but useful articles give employment in their production to a very considerable number of persons. At one large factory, upwards of 150 tons of brass are used annually for the

manufacture of pins. Were this quantity converted into the pins called ribbon-pins, half an inch in length, it would produce the enormous number of 100,800,000,000, or about 100 to each inhabitant of the globe. If placed in a straight line, they would extend to 787,500 miles, or sufficient to encircle the earth thirty times, or to hang three wires from our planet to the moon!

The wire is brass, and is reduced by the ordinary process of wire-drawing to the requisite thickness. In this process it is necessarily curved; to remove this it is rewound, and pulled through between a number of pins arranged at the draw, or straightening-bench; it is then cut into convenient lengths for removal, and finally reduced to just such a length as will make two pins. The pointing is done upon a steel mill or revolving wheel, the circumference of which is cut with teeth. Thirty or forty lengths are picked up at once; and, as in needle-making, the cast of hand given by the workman makes them revolve, and the whole are pointed at once: the same operation is performed with the other end. The process of heading is next effected as follows: A number of the pointed wires, now cut in two, are placed in the feeder of the machine; one drops in, is firmly seized, and, by means of a pair of dies, a portion of the metal is forced up into a small bulb; by a beautifully simple and automatic arrangement, it is passed into another, when a small horizontal hammer gives it a sharp tap, which completes the head. The white colour is produced by boiling in a solution of cream of tartar and tin. They are then dried, and passed into the hands of the wrappers-up.

The solid-headed pin was invented by Messrs. Taylor & Co. about twenty years since, and was then patented. The machinery used is of the most ingenious description, and was exhibited several years ago at the Polytechnic Institution. Some machines have been recently

made which are used for pointing the pins, and which are so rapid in operation that they point 600 a minute. There are several varieties of pins made. The smallest in common use is the kind employed by ribbon manufacturers, of which 300,000 go to the pound; and the largest are what are called blanket-pins, which are three inches long, and thick in proportion. Pins are sold by the ounce, and are produced so cheaply, through the perfection of the mechanism used, that some kinds are sold at a cost of little more than twopence over that of the metal of which they are formed!

A considerable manufacture of fish-hooks is also carried on in Birmingham. The process is very simple. Steel wire is cut into stated lengths, and is then placed in a little standard, where it is exposed to the action of a knife. The workman, causing the knife to descend, cuts up a piece of the metal near the end of the wire; this forms the barb of the hook, and is an operation conducted with wonderful precision and rapidity. The hook is then filed and smoothed, and is afterwards bent into its proper shape around a piece of brass let into a block of wood. The flat part of the hook is produced by a blow with a hammer. The hooks are polished by friction against each other in a revolving barrel, and are brought to their right temper, and to the peculiar and beautiful blue colour so well known, by being heated in animal charcoal.

Die-sinking, medalling, and coining, are important departments of the hardware manufactures, and, like the others which we have slightly noticed, these arts are carried on in greatest vigour at Birmingham. The trade is divided into two departments,—the heavy, which includes die-sinking for brass-founders' goods, chandeliers, cornices, cornice-ends, curtain-bands and pins, lamp-pillars and stands, coffin-furniture, &c.; the light department of die-sinking comprises coins, medals,

buttons, seals, labels, fancy goods, dish-covers, &c. The art of the die-sinker is one requiring much intelligence, steady application, attention, and delicacy of touch. It is nearly all done by master-manufacturers, who work with their own hands, for the least slip of the hand is so serious to the die, that only practised and experienced workmen can or will undertake the higher departments. A very large trade is that for coffin-furniture, the ornaments of which are made of iron, tinplate, or brass. Upwards of 200 persons are employed in Birmingham in the manufacture of these articles. In one of the factories it is said that forty tons per annum of cast-iron is used for making coffin-handles. There is also a great business in the manufacture of nails for coffins, of which it is said that sometimes 2,000 are used in ornamenting the coffin. The average weight of metal ornament and nails upon each coffin may be taken, at a low estimate, at 4½ lbs.; and, at this rate, the annual consumption of iron, tinplate, and brass, in the United Kingdom, amounts to at least 625 tons, which are buried in the ground, and lost to all useful purposes.

The process of die-sinking and medal-stamping has been well described in the Official Catalogue of the Great Exhibition, which was replete with illustrations of this interesting and extensive class of industrial occupations. A medal die is thus formed:—Steel of a uniform texture and suitable kind being selected, it is forged, softened by annealing, and the face and cheek for the collar turned. The design approved of, the die-sinker proceeds to cut away those parts of the greatest depth by means of small chisels: the more minute details are taken out by gravers, chisel-edged, and gouged steel tools fitted into wood handles, very short, and to fit the palm of the hand. As the work proceeds, proofs are taken in wax; when defective in form, the cutting is corrected, and if deficient in relief, it is sunk deeper.

It will, of course, be borne in mind that what will be relievo in the medal is intaglio in the die. The inscription is introduced by means of small letter-punches; then follows the hardening of the die, a stage of the business the most critical, as a defect in the steel will at once be made apparent thereby, and the labour of months rendered useless in a few minutes. If the die endures this, it has only another test, viz. the making of a "hub," or copy of the die in steel, and used for the correction of duplicate copies of the die. The danger in this case arises from the want of uniformity of hardness; if irregular, one portion of the original die must suffer, and become valueless.

Medal-making, or stamping, is thus carried on:—The press consists of a large and close-threaded screw, to the top of which a large wheel is attached horizontally. The bed of the press is fitted with screws to secure the die in its place; when this is done, the collar which gives the thickness of the medal is fitted on; the die forming the reverse of the medal is attached to the screw; a blank (a piece of metal cut out to form the medal) is then introduced. Motion is imparted to the wheel which operates upon the screw, a blow is given, and if the impression is soft and shallow, a medal is produced; but if deep, repeated blows are given to bring the impression up. Where bronze or silver is the material in which the medal is to be produced, as many as twenty or even thirty blows are necessary. The medal is then taken out of the press, the edge turned, and the operation is complete.

The Soho works at Birmingham were long celebrated for their medals, and for a long period nearly the whole of the copper coinage of the United Kingdom was produced there. Messrs. Boulton & Watt paid much attention to this important department of their multifarious trade, and it flourished while in their hands,

but failed in their successors', and the Mint on Tower-hill subsequently took all the coinage to itself. Large quantities of coins and medals are now struck at Birmingham for foreign countries occasionally; but the demand is very uncertain. There is a more constant trade in medals for the commemoration of public events, such as victories, the laying of foundation-stones, the opening of great buildings, and other events of chief moment. At such times, thousands of medals are struck off, and sent up in readiness for the day. The Great Exhibition led to the production of a vast quantity of these memorials, which were sold at a very cheap rate, and were, many of them, very well executed.

The production of tin-plate, and of articles made from it, is actively carried on at Birmingham, and is, in fact, a very important department of hardware manufactures. It is divisible into two parts,—the formation of the tin-plate from iron and tin, and the working up of this material into vessels. Much of the tin-plate is made in South Wales, but it is also largely manufactured in Birmingham and the Midland Counties. The iron is received in the state of pig, and after being puddled, it is passed through the rolling-mills till it is compressed into a sheet of several feet in length. While still red-hot, it is dexterously doubled or folded over, like a sheet of paper, by a workman; again passed into the furnace, and again under the roller; and so on, by successive repetitions of the process, until the original sheet has been eight times folded and rolled. It is then cut into squares or blocks by the steam shears; and when sufficiently cooled, the blocks, which are about a third of an inch in thickness, are handed over to boys, who bend the corners, somewhat after the fashion with which a bank clerk uses a pile of bank notes when he wishes to count them; and then rapidly "split" or separate them into the eight thinner sheets of which they are composed.

The next operation is that of "pickling" the plates, in vitriol diluted with hot water, to take the scale off and whiten them. But even after this has been done, the iron sheets are far from being ready to receive the thin coating of the more precious metal which gives them their name and usefulness. The men who preside over the vitriol-tubs, having done their part, transfer the sheets to women, whose business is to rub them slightly with sand, and then to dip them in cold water to remove all traces of vitriol. After they have been cleaned from the vitriol, the plates are placed in a furnace for eight or nine hours, to be annealed; but as the annealing dulls the brightness which the vitriol gave them, they suffer the process of cold rolling, to give them once more the necessary polish. It is then softened by annealing, and the plate is now nearly ready to receive its coating of tin. It is first placed in what is called a "pickle"—in fact, a dilute solution of sulphuric acid,—and is afterwards plunged into a vessel of boiling oil, where it is allowed to remain for a quarter of an hour. Close by this cauldron is another partly filled with melted tin, on the surface of which a layer of oil floats. The workman dips the iron plate into the fluid metal, and leaves it there for ten or twelve minutes, at the end of which time it adheres, and it is drawn out covered with a brilliant coating of the tin. The surface of the plate is then brushed, so as to remove the superfluous tin, and the plate is then rubbed with bran, and polished with sheepskin with the wool on. It is then packed up in boxes containing 225 in each. As an example of the celerity acquired by long practice, it is stated that one woman has been known to polish as many as 12,250 sheets in a working day. The iron is now effectually protected from oxidation, and the material becomes consequently adapted for any of the multifarious uses of domestic life.

The principal articles manufactured of tin-plate are, pots, pans, kettles, and culinary utensils of various kinds; tea-trays, tea-urns, tea-pots, coffee-pots, toast-racks, beer-jugs, water-pans, canisters, dish-covers, candlesticks, cash-boxes, lanterns, shower-baths, foot-baths, slop-pails, coal-scuttles, coal-vases, plate-warmers, patty-pans, jelly-moulds, cake-moulds, tart-pans, &c.

These are wrought into form by workmen employed in large factories, and called tin-plate workers. Machinery is also used for stamping and burnishing, but it is of a very simple kind; and much depends upon the skill and expertness of the workman in the use of the soldering iron and the other simple tools of his craft. So surprisingly has the power of production increased, that a good tea-pot, which twenty years ago would have cost thirty shillings, can now be made for two shillings. In all the articles intended for kitchen use, or in nearly all, the tin is left in its natural state on the surface of the article, except that it is highly polished; but a very large trade is also carried on in what is called japanning, to which some notice must be given.

Japanned tin ware is in such universal domestic use, that it will be interesting to describe its mode of production. Baths of all sorts, trays, pails, toilet-services, jugs, pans, coal-scuttles, and a great variety of other articles, are formed of japanned ware. The mode of giving to the articles their peculiar appearance may be illustrated by the following account of the production of a tea-tray, taken from the pages of the *Morning Chronicle*, and forming part of a series of papers on the Birmingham trades, to which we are much indebted for our information in the present chapter.

"After the iron is formed into the required shape and size, it is rubbed with a particular sort of stone, procured from Bilston, until it becomes smooth; it is then handed to a woman, who lays on one or two thick coats of colour

mixed with varnish, and places the tray in a stove to dry; it is then varnished three or four times, and again thoroughly dried, after which it is rubbed, smoothed, and polished, and prepared to be handed to the printers' room, where it is ornamented according to the design required. The design is engraved upon a copper plate, and the impression is taken by rubbing into the cavities of the engraving an oily composition which adheres in the form of the design to the paper pressed upon it. The printed paper is laid upon the tray, and rubbed with flannel, so that the oily substance adheres to it. The paper is then lifted off, and gold, silver, or bronze dust plentifully scattered upon the mixture as it stands in the tray. This is rubbed with flannel, and all the details of the design are thus brought out, and as accurately transferred as if the tray itself had been subjected to the ordinary process of printing from the copper plate. The colours are then made fast by varnishing and drying, after which the tray is smoothed by rubbing it with rotten-stone, and finally polished with the naked hand. All the painting, varnishing, and polishing is done by females; and as in giving the last polish to superior tin-plate and Britannia-metal wares, so also in japanned work,—a soft female hand is necessary to communicate that exquisite polish which we find on these articles when new and exposed for sale. It is stated that the females employed in polishing the best goods never engage in the rougher household duties, such as scouring the floor, or even handling the broom, lest their hands should lose the soft touch which is necessary to give the last beautiful polish to those articles of manufacture."

Britannia-metal is becoming a great rival to the tin-plate trade, and is most extensively used for a great variety of articles. It is greatly in demand for tea-spoons, and tea and coffee-pots, which are made in

enormous numbers. It is an alloy of tin, antimony, copper, and brass, melted together and cast into ingots. It is a very soft metal, easily worked, of a whitish colour, and capable of taking a very high polish. Sheffield and Birmingham are the chief centres of this manufacture. Much of the work used to be done, and still indeed is effected, by stamping in dies, and the required figure is given to objects in this way very quickly. But a most singular and ingenious method has lately been introduced, which resembles the production of pottery on the wheel: this is called spinning!

A spindle is made to revolve rapidly in a horizontal position, and a wooden chuck is fixed on it, or a model of so much of the article to be made as will allow the metal to slip off the wood after it has been closed upon it. A piece of sheet-metal, which is extremely soft and ductile, is then cut of the required size, and is lightly fixed upon the revolving model, and it is now gradually pressed by the workman, until it yields itself and takes the form of the model, without either crumpling or tearing. By this simple process the upper and lower parts of the body of an ordinary tea-pot are made. The lid and bottom are stamped, the spouts and handles are cast, and the whole of the pieces are then readily soldered together, and sent to be burnished and cleaned. The spinning process has been of immense influence in facilitating, and also in economising, the production of Britannia-metal goods.

It would be both tedious and useless to enumerate the various articles of domestic use which are now made of this easily wrought material. It is the working man's plate, and is often a not unimportant part of the furniture of those higher in life. Many articles which are electro-plated are made of Britannia-metal; and they

wear well, because the edges do not differ sensibly in colour from the surface even after the coating of silver has worn away.

In close connexion with the subjects which have recently occupied our attention, is the art of plating with gold and silver. It has been well said that the stock in trade of a Birmingham gilder only consisted of a guinea, an iron pot, a little fuel, and a garret. These, at any rate, were all the absolute requisites for the covering of jewellery and toys with an infinitely small layer of gold. Brooches, chains, buckles, bracelets, clasps, &c., all come under the denomination of gilt toys in the language of Birmingham, and were formerly made in inconceivably large quantities, until at last the markets of the world were glutted with these meretricious articles, and as a natural result the trade fell into ruin. All sorts of sham jewellery were made at Birmingham, until at last the very name was suggestive of a worthless object—pretentious in appearance, but in reality of most insignificant value. Plating with gold and silver was formerly much done at Birmingham, but has now given way to the electro-plating, which is carried on to an immense extent in that town.

Sheffield was the great centre of the plated goods manufacture, and has become celebrated for the general excellence of this class of work throughout the world. The method adopted has been described in the following manner by a Sheffield manufacturer:—

An ingot of copper or of German silver being cast, and the surfaces carefully prepared by filing so as to remove all blemishes, and a piece of silver having likewise one surface perfectly cleaned, are tied together by means of iron wire. A mixture of borax and water is then drawn round the edges with a quill. They are next placed in a common air furnace to be heated to a

proper temperature, and having a small aperture in the door through which the workmen can observe when that temperature is attained. During the union of the two bodies, the surface of the silver is seen to be drawn into intimate contact with the copper or German silver, and the moment this takes place is the signal for removing the bar from the furnace. The appearance of incipient admixture on the edges of the silver shows how perfect the fusion has been, as this oozing of the metal is not in consequence of any extraneous application of solder, &c. but entirely the effect of the fusion of the surfaces of the two bodies. The ingot thus obtained may now be rolled into sheets of any required thickness, and the union of the two metals is so perfect, that they continue inseparable even when drawn out into the finest wire.

In the manufacture of a tray out of this plated metal, the metal is first cut to the proper shape. The edge of the tray is then formed by hammering it round a bar of steel, and the whole is polished by beating it with a hammer either upon one or both sides. The ornaments are executed with much care, and great attention is necessary lest the tool should cut too deep and reveal the baser metal beneath. The chasing is done by means of small punches of various shapes, and thus the metal is not cut out but forced in. The last operation is the burnishing, which is done by women with tools of blood-stone and steel, and with the assistance of soap-suds.

Electro-plating has, to a very large extent, replaced the older method of fire-plating, and was first applied on a large scale by Messrs. Elkington, in 1840. Its essential principles have been already noticed. The manufacture is now carried on by Messrs. Elkington on the largest scale at Birmingham.

The articles, or parts of articles, having been wrought up with as much care as if they were of solid gold or silver, and having undergone from first to last all the processes from the moulding to the chasing and putting together, are brought to the plating department. Here a powerful galvanic battery is raised. In front of it are ranged several tanks or troughs filled with a dark-looking fluid, of the colour of strong tea. The fluid is a solution of silver formed by dissolving an oxide or salt of silver in cyanide of potassium. The articles desired to be coated are attached to a wire in connexion with the positive or zinc pole of the electrical apparatus, and immersed into the solution—a plate of silver, in connexion with the negative or copper pole of the apparatus, forming the opposite pole, which plate is dissolved and transferred to the article by the current of electricity passing between them. The length of time required for the operation depends upon the body of silver desired, and also upon the proportional amount of silver in the solution. Among other marvels of the Electrotype process, it has been stated that even a spider's web has been plated with gold!

A very large trade is also carried on at Birmingham in the manufacture of metallic bedsteads, and of brass-founding for upholsterers, and of gas-fittings. Locks, fire-irons, saddlers' ironmongery, and every description of hardware, are produced there in immense quantities, and are thence distributed to the remotest quarters of the world. Few machines are made at Birmingham in comparison with those produced by the renowned machine-shops of Manchester, to which we have already adverted. A considerable number of steam-engines are, however, made in this district, together with the simple instruments used in general hardware manufactures. But Birmingham does not turn out such mechanisms as power-looms, mules, throstles, and the exquisite auto-

matic machinery of the textile fabric manufactures. The representatives of Messrs. Boulton & Watt still manufacture steam-engines of the best kind; and to this alone do they direct their attention, the once multifarious trade of the Soho works being entirely gone.

In the trades noticed in this chapter, and in allied departments of industry, a very large portion of the operatives of the Midland districts are busily engaged; and certainly a more striking picture of hard-handed and hard-working industry could not be found than is presented by Birmingham, Wolverhampton, Walsall, and the surrounding country. In every direction rise volumes of dense smoke from countless chimney-stalks, and the toiling beam of the steam-engine in perpetual oscillation forms a prominent feature in the landscape. Pulleys, ropes, iron-roads, worn-out boilers and fly-wheels, furnaces vomiting out smoke by day and fire by night, form the inanimate detail of the scene, and soot-begrimed men and women its living accompaniments.

One feature of the hardware trade must be noticed before we close, and that is its tendency to deterioration in the quality of its products. It is acknowledged by the manufacturers themselves, that such is the demand for articles of excessively low value, that it is impossible to produce really solid and durable articles at remunerative prices. All the domestic utensils of the present day are inferior in solidity and durability to those made twenty years ago. They are better finished because of the introduction of machinery into the manufacture, but they are often quite unfit for prolonged use, and, in some instances, are absolutely unfit for use at all! In some of the candlesticks which are electro-plated, and appear of the best make to the eye, and weighing the proper weight of good metal, namely, 24 oz.; on being taken to pieces, it was found that

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22 oz. of this weight was actually made up of clay introduced into the bottom and covered over with a thin sheet of metal: the total weight of metal in them was only 2 oz.! Tea-pots also are frequently produced which fall to pieces with the weight of the water put into them. The result of this demand for cheap things, and its consequent supply of "slop-work," as it is called, is, as may be imagined, most injurious to the district itself. Ultimately, a trade carried on in such a manner, and resting on such a basis, must come to nothing. And such, in many departments of hardwares, has already been the case. It may be hoped, then, that the buyers, on the one hand, will in future have more regard to the solidity than to the low price of the things they purchase, and that the sellers may more conscientiously exert themselves to the production of really good and lasting wares. For many years the vulgarism—a "Birmingham thing"—applied as a term of contempt to a trashy article, has been only too justly merited; and it is to be hoped that in due time this most industrious and interesting locality may become as celebrated for the worth of its products as it has heretofore been notorious for their opposite character.

Our survey of the industrial pursuits of our own and other countries is now completed. Our chief object has been to present a general view of the present condition of what we may call mechanical industry—of machinery and mechanical arts. It would, therefore, have been foreign to our purpose to have entered on the higher ground of ornamental art, of sculpture, and the fine arts generally. Neither did it appear desirable to retread the field occupied by the humbler arts, such as those of the leather-dresser, the furrier, the soap and perfumery maker, and many other arts, which received their full illustration in the Great Exhibition of 1851. The

writer would hope the completion of his plan may have been attended with instruction to the reader of this work. Nor can he believe that the most casual survey of a series of subjects so important as those upon which this work treats, can be accomplished without awakening thoughts of wonder at what man has done; and these, in every rightly-disposed mind, will be associated with feelings of gratitude and reverence for that Superior Mind which has made man the superior being that he is.

THE END.

R. CLAY, PRINTER, BREAD STREET HILL.